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U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE **TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371**		ATTORNEY'S DOCKET NUMBER 1454.1122 09/980488
INTERNATIONAL APPLICATION NO. PCT/DE00/01528	INTERNATIONAL FILING DATE 15 May 2000	PRIORITY DATE CLAIMED 1 June 1999
TITLE OF INVENTION METHOD, SYSTEM AND COMPUTER PROGRAM FOR DESIGNING A TECHNICAL SYSTEM		
APPLICANT(S) FOR DO/EO/US Florian HARZENETTER et al.		

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a FIRST submission of items concerning a filing under 35 U.S.C. 371.
2. ☒ This is an express request to immediately begin national examination procedures (35 U.S.C. 371(f)).
3. ☒ The US has been elected by the expiration of 19 months from the priority date (PCT Article 31).
4. ☒ A copy of the International Application as filed (35 U.S.C. 371(c)(2))
   a. ☒ is transmitted herewith (required only if not transmitted by the International Bureau).
   b. ☐ has been transmitted by the International Bureau.
   c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
5. ☒ A translation of the International Application into English (35 U.S.C. 371(c)(2)).
6. ☐ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3))
   a. ☐ are transmitted herewith (required only if not transmitted by the International Bureau).
   b. ☐ have been transmitted by the International Bureau.
   c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US)
7. ☐ A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
8. ☐ An oath or declaration of the inventor (35 U.S.C. 371(c)(4)).
9. ☐ A translation of the Annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 10-15 below concern document(s) or information included:

10. ☒ An Information Disclosure Statement Under 37 CFR 1.97 and 1.98.
11. ☐ An assignment document for recording.
    Please mail the recorded assignment document to:
    a. ☐ the person whose signature, name & address appears at the bottom of this document.
    b. ☐ the following:
12. ☒ A preliminary amendment.
13. ☒ A substitute specification
14. ☐ A change of power of attorney and/or address letter.
15. ☒ Other items or information:

PCT EASY forms filed with International Application, copy of cover page of International Application as published, International Search Report, and International Preliminary Examination Report.

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☒ The U.S. National Fee (35 U.S.C. 371(c)(1)) and other fees as follows:

CLAIMS	(1) FOR	(2) NUMBER FILED	(3) NUMBER EXTRA	(4) RATE	(5) CALCULATIONS
	TOTAL CLAIMS	13 -20=	0	x $ 18.00	0.00
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	MULTIPLE DEPENDENT CLAIM(S) (if applicable)			+$280.00	0.00
	BASIC NATIONAL FEE (37 CFR 1.492(a)(1)-(4): ☐ Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO ......$1,040 ☐ International preliminary examination fee (37 C.F.R. 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO.........$ 890 ☐ International preliminary examination fee (37 C.F.R. 1.482) not paid to USPTO but international search fee (37 C.F.R. 1.445(a)(2) paid to USPTO...$ 740 ☐ International preliminary examination fee paid to USPTO (37 CFR 1.482) but all claims did not satisfy provision of PCT Article 33(1)-(4)...........$ 710 ☐ International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(2) to (4) ....$ 100				$890.00
	Surcharge of $130 for furnishing the National fee or oath or declaration later than ☐ 20 ☐ 30 mos. from the earliest claimed priority date (37 CFR 1.482(e)).				0.00
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			SUBTOTAL		974.00
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			TOTAL NATIONAL FEE		974.00
	Fee for recording the enclosed assignment (37 CFR 1.21(h)).				+40.00
			TOTAL FEES ENCLOSED		1014.00

a. ☒ A check in the amount of $1014.00 to cover the above fees is enclosed.

b. ☐ Please charge my Deposit Account No. 19-3935 in the Amount of $ to cover the above fees. A duplicate copy of this sheet is enclosed.

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21171
PATENT TRADEMARK OFFICE

SUBMITTED BY: STAAS & HALSEY LLP

Type Name	Richard A. Gollhofer	Reg. No.	31,106
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Docket No.: 1454.1122

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re the Application of:

Florian HARZENETTER et al.

Serial No. Group Art Unit:

Confirmation No.

Filed: (concurrently) Examiner:

For: METHOD, SYSTEM AND COMPUTER PROGRAM FOR DESIGNING A TECHNICAL SYSTEM

PRELIMINARY AMENDMENT

Assistant Commissioner for Patents
Washington, D.C. 20231

Sir:

Before examination of the above-identified application, please amend the application as follows:

IN THE TITLE:

Please REPLACE the Title with the following:

-- SYSTEM FOR DESIGNING A TECHNICAL SYSTEM--.

IN THE ABSTRACT:

Please DELETE the Abstract in its entirety and substitute the attached new Abstract.

IN THE SPECIFICATION:

Please REPLACE the Specification in its entirety and substitute the attached new Substitute Specification.

IN THE CLAIMS:

Please DELETE claims 1-12 without prejudice or disclaimer and ADD new claims 13-25 in accordance with the following:

13. (NEW) A method for designing a technical system, comprising:

prescribing a problem structure for the technical system, the problem structure including functionalities;

rating the problem structure based on prescribed criteria;

grouping the functionalities using said rating;

designing the technical system based on said grouping.

14. (NEW) The method as claimed in claim 1, wherein said grouping of the functionalities is performed iteratively.

15. (NEW) The method as claimed in claim 1, wherein said grouping of the functionalities uses at least one of neural networks and genetic algorithms.

16. (NEW) The method as claimed in claim 1, wherein said grouping uses a simulated annealing method.

17. (NEW) The method as claimed in claim 1, wherein said designing of the technical system comprises at least one of a new design; adjustment; layout; rating, assessment; simulation; and validation by inspection.

18. (NEW) The method as claimed in claim 1, wherein the design is used to ascertain a functional network for the technical system.

19. (NEW) The method as claimed in claim 1, wherein the prescribed criteria are quality criteria.

20. (NEW) The method as claimed in claim 1, wherein the prescribed criteria comprise at least one of usability; modifiability; maintainability; checkability; portability; integrity, development complexity; performance; reusability; and reliability.

21. (NEW) The method as claimed in claim 1, wherein the prescribed criteria are weighted.

22. (NEW) The method as claimed in claim 1, wherein the functionalities affect operating scenarios, and the operating scenarios in turn affect at least one benefit.

23. (NEW) A system for designing a technical system, comprising:

an input unit to receive data defining a problem structure for the technical system, the problem structure including functionalities; and

a processor unit, coupled to said input unit, to obtain a rating of the problem structure based on prescribed criteria, to group the functionalities using the rating, and to design the technical system based on grouping of the functionalities.

24. (NEW) At least one computer readable medium storing at least one computer program to control a processor to perform a method for designing a technical system, said method comprising:

prescribing a problem structure for the technical system, the problem structure including functionalities;

rating the problem structure based on prescribed criteria;

grouping the functionalities using said rating;

designing the technical system based on said grouping.

25. (NEW) A method for designing a technical system, comprising:

prescribing a problem structure for a functional network of the technical system, the problem structure including functionalities that affect operating scenarios that in turn affect at least one benefit;

rating the problem structure based on quality criteria;

iteratively grouping the functionalities based on said rating, using at least one of a neural network and a genetic algorithm;

designing the technical system based on said grouping.

REMARKS

This Preliminary Amendment is submitted to improve the form of the English translation as filed. It is respectfully requested that this Preliminary Amendment be entered in the above-referenced application.

In accordance with the foregoing, claims 1-12 have been canceled and claims 13-25 have been added. Thus, claims 13-25 are pending and are under consideration.

A substitute specification is also being filed herewith. The substitute specification is accompanied by a marked-up copy of the original specification.

If there are any questions regarding these matters, such questions can be addressed by telephone to the undersigned. Otherwise, an early action on the merits is respectfully solicited.

If there are any additional fees associated with filing of this Preliminary Amendment, please charge the same to our Deposit Account No. 19-3935.

Respectfully submitted,

STAAS & HALSEY LLP

Date: 12/3/01

By: Richard A. Gollhofer

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SUBSTITUTE SPECIFICATION

TITLE OF THE INVENTION

SYSTEM FOR DESIGNING A TECHNICAL SYSTEM

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application is based on and hereby claims priority to German Patent Application No. 19925214.9 filed on June 1, 2001, the contents of which are hereby incorporated by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0002] The invention relates to a method, an arrangement and a computer program for designing a technical system.

2. Description of the Related Art

[0003] One aim of systems engineering is to design, simulate or lay out a technical system. In this respect, a complex technical system is usually so extensive that it is first appropriately segmented into subsystems. In this context, subdividing the overall technical system into such subsystems provides no kind of certainty that the subdivision will also furnish the appropriate (in terms of the design) subsystems. In particular, the breakdown is often performed intuitively by experts who have accumulated experience over many years. However, the complexity of the overall technical system means that there is no kind of assurance, and there is no means of causally verifying, that such intuitive breakdown of the overall technical system is particularly beneficial or even optimal.

[0004] IEEE standard 1220/1994)] lays down a system definition (SEP) which contains a set of rules for breaking down a complex technical system into subsystems.

[0005] A "simulated annealing" method is known from Kirkpatrick, S., C.D. Gelatt Jr., M.P. Vecchi, 1983: "Optimization by Simulated Annealing", Science, V. 220, No. 4598, pp. 671-680.

SUMMARY OF THE INVENTION

[0006] The object of the invention is to provide a way of designing a technical system in which the technical system is subdivided into appropriate functionalities and hence the design of the technical system is significantly simplified.

[0007] In this context, functionalities are to be understood to mean, in particular, functional units in the system, that is to say the response of the system from the point of view of a user, and also demands on functions (the system acts itself in this case).

[0008] To achieve the object, the invention specifies a method for designing a technical system in which a problem structure for a technical system is prescribed, which problem structure comprises a plurality of functionalities. The problem structure is rated in relation to prescribed criteria. The rating is used to group the functionalities and to design the technical system on the basis of the grouping.

[0009] A particular advantage in this context is that the grouping is done automatically using the rating of the problem structure on the basis of the prescribed criteria. Functionalities are thus obtained which are suited to one another particularly in respect of the design of the technical system.

[0010] One development is that the functionalities are grouped iteratively.

[0011] In this context, the problem structure may comprise not only the functionalities but also characteristic quantities providing a structure on a plurality of levels, for example operating scenarios or benefits. The functionalities may preferably have specific operating scenarios. These operating scenarios themselves have a particular benefit. The relationship between functionalities and operating scenarios can be weighted individually. The same applies for the relationship or the relation between operating scenarios and associated benefit. Another development is for the functionalities to be grouped using neural networks or using a generic algorithm.

[0012] Another development is for the grouping to be done using a "simulated annealing" method.

[0013] One refinement of the invention is that the design comprises one of the following options:

1. New design:
   New design aims to create a technical system which has preferably not existed previously in this form.
2. Adjustment:
   In the case of adjustment, an already existing technical system is preferably adapted. This

can be done with regard to optimized, improved or extended parameters. Partial conversion or partial redesign of the technical system can also be regarded as adjustment.

3. Layout:
   Layout preferably relates to technical installations which, in order to meet particular technical specifications, need to have predefined dimensions, for example. Thus, for example, a factory can be laid out for producing a particular minimum quantity of a prescribed product. This minimum quantity results in specifications regarding size, number of production lines, power consumption, infrastructure etc.

4. Rating, assessment:
   The design can also be used to rate or to assess a technical system. Particularly in the case of intuitively designed technical systems, it is advantageous to find out for certain about a level of efficiency of this technical system. Such a rating is also very useful when searching for improvement potential with regard to a more economical way of working.

5. Simulation:
   The design reflected in the simulation is preferably used to present a preliminary stage for a real embodiment of the technical system. Often, the simulation can be used to determine a suitable technical system which, when produced in practice, results in high cost and therefore needs to be predefined particularly precisely and versatilely in the course of simulative planning.

6. Validation:
   The design also permits validation (inspection), on the basis of which the technical system is validated in terms of size, layout, functionality, etc. in comparison with the specifications made. The result of validation may be, by way of example, a binary decision, for example "suitable" or "not suitable".

[0014] Another refinement involves the design being used to ascertain a functional network for the technical system. The functional network is preferably suitable as a preliminary stage for the practical implementation of the technical system.

[0015] Another refinement is that the prescribed criteria comprise quality criteria.

[0016] In this context, the prescribed criteria can comprise at least one of the following options: Usability, modifiability, maintainability, checkability, portability, integrity, development complexity, performance, reusability, reliability. Correspondingly, numerous other prescribed criteria are possible.

[0017] Another refinement is that the prescribed criteria are weighted. If, by way of example, the functionality is linked to a weighting in terms of a particular criterion (which is affected in a particular way by this functionality) allows a weighted assessment for the design, in particular when the functionalities are grouped.

[0018] The object is also achieved by specifying an arrangement for designing a technical system, which arrangement is provided with a processor unit which is set up such that

a) a problem structure for the technical system can be prescribed, which problem structure comprises (a plurality of) functionalities;

b) the problem structure can be rated on the basis of prescribed criteria;

c) the rating is used to group the functionalities;

d) the technical system can be designed on the basis of the grouping.

[0019] In addition, the object is achieved by specifying a computer program which is set up such that, when running on a processor unit, it performs the following steps:

a) a problem structure for the technical system can be prescribed, which problem structure comprises (a plurality of) functionalities;

b) the problem structure is rated on the basis of prescribed criteria;

c) the rating is used to group the functionalities;

d) the technical system is designed on the basis of the grouping.

[0020] The arrangement and the computer program are particularly suitable for implementing the inventive method or one of its developments explained above.

BRIEF DESCRIPTION OF THE DRAWINGS

[0021] These and other objects and advantages of the present invention will become more apparent and more readily appreciated from the following description of the preferred embodiments of the invention are illustrated and explained below with reference to the drawings, in which

Figure 1 is a block diagram of a multilevel problem structure;

Figure 2 is a table indicating an association between quality features and functional metrics;

Figure 3 is a block diagram of a solution structure in which functionalities are grouped into individual functions;

Figure 4 Figures 4A and 4B form a block diagram of one possible problem structure;

Figure 5 is a table containing weightings for the functional metrics;

Figures 6A and 6B form a block diagram of a solution structure for a vending machine;

Figure 7 is a block diagram of a functional network for the vending machine;

Figure 8 is a block diagram of a processor unit.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0022] Reference will now be made in detail to the preferred embodiments of the present invention, examples of which are illustrated in the accompanying drawings, wherein like reference numerals refer to like elements throughout.

[0023] Figure 1 shows a hierarchical problem structure. In this case, a hierarchical level 101 comprises a plurality of functionalities (1 to 7), a hierarchical level 102 comprises a plurality of operating scenarios (1 to 3), and a hierarchical level 103 comprises a plurality of benefits (1 and 2). Preferably, the problem structure is determined at the start from demands made on a product by a customer. The problem structure shows functionalities 101 which the customer expects from the product. The operating scenarios 102 take account of operating situations in which the customer (user) would like to use the functionalities 101 described. Finally, the hierarchical level 103 contains the benefit which the customer (user) would like to derive from the product. In the example in Fig. 1, the functionalities required for the specific operating situation and the benefits relating to those operating scenarios in which they are to be provided are associated with the operating scenarios.

[0024] A use u_x can be agreed between individual functionalities and operating scenarios (see reference 104). In Fig. 1, the functionality 1 has a use u_1 relating to the operating scenario 1, and a functionality 4 has a use u_4 relating to the operating scenario and a use u_6 relating to the operating scenario 2. A complete relationship between the use 104 of the individual functionalities 1 to 7 and the operating scenarios 1 to 3 is given by the following relations:

operating scenario 1 = $\{u1_{f1}, u2_{f2}, u3_{f3}, u4_{f4}\}$

operating scenario 2 = $\{u5_{f3}, u6_{f4}, u7_{f5}, u8_{f6}\}$

operating scenario 3 = $\{u9_{f6}, u10_{f7}\}$

In this context u_x denotes the use, with fi (i=1...7) respectively identifying the functionality 1 to 7 linked to the use.

[0025] Correspondingly, the operating scenarios 102 provide a useful contribution n_L for the benefit 103 (reference 105). In the example in Fig. 1, the following relation is obtained:

$$\text{benefit } 1 = \{n1_{B1,}\ n2_{B2},\ n3_{B3}\}$$

$$\text{benefit } 2 = \{n4_{B3}\}$$

Bi (i = 1 to 3) identifies the respective operating scenario providing the respective useful contribution n_L for the benefit 103 indicated above.

[0026] Figure 2 shows an association between quality features and functional metrics. The method presented here makes it possible to improve different quality features of a technical system. There are various quality features in this respect; the list below is not conclusive:

- usability
- modifiability
- maintainability
- checkability
- portability
- integrity
- development complexity
- performance
- reusability
- reliability

[0027] Depending on the respective technical system, quality features have different significance or priority. By way of example, reliability and development complexity are crucial quality features for a satellite; for durable, easily accessible products, for example an aircraft carrier or a power station, quality features such as modifiability and maintainability are of particular significance.

[0028] Figure 2 shows, in the form of a table, an example of how quality features can be shown above structural features and at what point the improvement or optimization of the technical system can take effect, individually, on the basis of prescribed functional metrics. The weighting of the quality features for the respective technical system is used to derive a profile of structural features, which profile will be rated in detail by functional metrics.

[0029] Figure 3 shows a solution structure in which functionalities have been grouped into individual functions. The problem structure from Fig. 1 and the weighting of the quality

demands on the product from Fig. 2 are used as a basis for determining a solution structure (a combination of functionalities into functions). Each function, that is to say each group of functionalities, describes a response from a subsystem, in particular from an advantageously determinable part of the overall technical system. In this context, the groups are determined such that structural features derived from the quality features take the best possible form. In Fig. 3, functionalities 1 and 2 have been combined to give a function 1, functionalities 3 to 5 have been combined to give a function 2 and functionalities 6 and 7 have been combined to give a function 3.

[0030] The weighted quality features are used to derive a weighting for the functional metrics. The structural features of the solution are rated on the basis of the functional metrics. The structural features which are to be rated on the basis of the functional metrics are described individually below:

1. Complexity:
   The complexity rates the level of significance of the function associated with a benefit or an operating scenario to the overall system.
2. Modularity:
   Modularity assesses the size of the proportion of those functions in a benefit or in an operating scenario which are exclusively associated with the benefit or operating scenario under consideration.
3. Redundancy:
   Redundancy rates whether a function is contained in duplicate or a plurality of times in the system.
4. Involvement:
   Involvement rates the significance of a function to the overall system.
5. Coupling:
   Coupling rates how closely the functions in the system are linked to one another.
6. Cohesion:
   Cohesion rates the strength of the internal link for a function.
7. Efficiency:
   Efficiency rates the level of complexity for providing a benefit or an operating scenario in relation to the significance of the benefit to the overall system.

OPTIMIZATION:

[0031] A solution is chosen which serves as a starting point for an optimization algorithm. This solution is rated by the previously weighted functional metrics. This weighting and the results of the rating of the structural features are then used to ascertain an overall rating. This overall rating shows how well the system structure under consideration meets the quality demands made.

[0032] Taking the initial configuration as a basis, the optimization algorithm is used to determine and rate new functions (or groups of functionalities). The optimization algorithm preferably searches for alternative solution structures until a suitable configuration has been found.

OUTPUT:

[0033] The method described is preferably suitable for automatically deriving suitable structures from demands on a technical system. In this context, the solution structure serves as a basis for determining a functional network in which the interfaces between the functions are stipulated on the basis of the solution structure. The dependencies between the functions to be provided are ascertained by providing a rating for whether functions are used together in particular situations or for particular purposes: their use together implies, by way of example, flows of energy, material or information between the functions, or at least a control flow which controls the use of the functions together.

[0034] If the data are conditioned appropriately, already existing architectures can be rated, assessed, validated, simulated and improved.

[0035] The functional metrics can also be used to check the fundamental structure, for example to determine whether the envisaged response and use of the product are at all able to meet prescribed quality demands, or whether, instead, the problem structure itself still requires further improvements (for example addition of redundancies, decoupling of individual operating states).

EXAMPLE

[0036] The method described above is explained below with the aid of a vending machine (for example for confectionery, cigarettes or drinks).

Problem structure:

[0037] First, the demands on the product are modeled in the problem structure. Figure 4 shows one possible problem structure:

a) An operator of the vending machine wishes to provide various benefits by operating the vending machine. Firstly, he wants to make a profit by selling the products he offers and by collecting the resultant proceeds of the sale, and secondly, by varying the products offered, he wants to ensure that he can always satisfy the requirements of his customers as well as possible.

b) These benefits are provided by the machine in various operating situations: firstly, the machine accepts money from the customer and then allows him to select one of the products offered. After the selection has been made, the appropriate product is dispensed, if appropriate together with change. From time to time, the vending machine needs maintaining, in the course of which the products offered can be replaced and the collected proceeds of sale are removed from the machine.

c) In the individual operating situations, the machine needs to respond in accordance with a product specification. This response is described by the functionalities 401 (numbered 1 to 20). The functionalities firstly describe the modes of behavior required in the respective operating situation and secondly also the state conditions for changing between two operating situations.

[0038] Figure 4 also shows that the associations between the individual elements (functionalities, operating scenarios and benefits) of the problem structure can be weighted. Alternatively, the method can also be applied to unweighted problem structures. Weighting is used to give a more precise description of the structure of the elements in relation to one another; important features of the problem structure are preferably defined by the presence or absence of the associations.

[0039] Information required for producing the problem structure can frequently be taken from the product specification. The problem structure reflects the customer's ideas about the response of the product without taking into account possible technical implementations. Besides the functionalities 401, Fig. 4 shows operating scenarios 402 (numbered 1 to 5) and benefits 403 (numbered 1 to 3). There is also a link between individual functionalities and particular operating scenarios, summarized as use 404. A corresponding relation between individual operating scenarios and individual benefits is shown in Fig. 4 as a useful contribution 405. The individual associations 404 and 405 are weighted, as described above.

QUALITY FEATURES:

[0040] The vending machine to be developed (see above) has various demands made on it in the course of its life cycle. Since the vending machine is produced in large numbers, a development phase takes on rather low significance. This means that rather low significance is attached to the quality features "development complexity", "checkability" (testability of the individual modules during the development and production phase) and "reusability" (use of commercially available/already developed assemblies for the vending machine system). In the example, the quality features together have the weighting 0.25 (cf. top row in Fig. 5). By contrast, the operating phase in the product life cycle is much more significant to the success of the product "vending machine". In this case, the relevant quality features are "usability" from the point of view of the customer, and "maintainability", "modifiability" and "reliability" from the point of view of the machine operator. The weighting for these quality features prescribed by the operation of the vending machine is 0.75 (cf. first row in Fig. 5 in this case too). The sum of all the weightings for all the quality features has been normalized to 1 in the example. The association matrix 503 is used to calculate the weighting factors 502 for the functional metrics from the weightings 501. In this context, the weighting for a functional metric $g(F_j)$ is the sum of the product of the association matrix Z_{ij}, the weighting factor w_i and the weighting $g(Q_i)$ for all i when j = constant.

[0041] Note: Z_{ij} is an element in the association matrix, w_i is the weighting factor for the product and $g(Q_i)$ is the weighting for a quality feature.

[0042] The following is obtained:

$$g(F_j) = \Sigma_i (Z_{ij} * g(Q_i) * w_i).$$

[0043] As stated above, the sum of the weightings for the quality features and the weightings for the functional metrics is preferably equal to 1.

[0044] The result of a weighting determined in this way is that an overall weighting can be calculated which is used to indicate the extent to which the solution structure determined for the technical system covers particular quality demands.

RATING:

[0045] The functional metrics rate the type and "strength" of the links between the individual elements of the solution structure. Hence, not just the links between the elements of the structure are taken into consideration, but also which of the functionalities are combined to give a function (grouping!).

CALCULATION EXAMPLE (SEE FIG. 4):

[0046] The strength of the link between the functionality "1. Coins from customer are accepted as payment" and the benefit "1. Sale of the product selected by the customer" is

$$0.1 * 0.25 = 0.025$$

[0047] The significance of the functionality to the overall system is calculated on the basis of the link to the overall system benefit, in which the benefits 1, 2 and 3 each have the proportion 0.33: besides the link just described relating to operating scenario 1 and benefit 1, the links via operating scenario 2 to benefit 1 and via operating scenario 1 to benefit 2 also contribute to the significance of the functionality. This significance of the functionality is calculated as the sum of the three associations:

$$0.1 * 0.25 * 0.33 + 0.1 * 0.33 * 0.33 + 0.2 * 0.25 * 0.33 = 0.03564$$

[0048] If the significance of functions is calculated as groups of functionalities for the overall system, the significances of the individual functionalities contained in the group are added.

[0049] This described method of calculation is used for the different functional metrics in order to rate different properties of the system. Specifically, the procedure for calculating the various values is as follows:

1. Complexity:

   Complexity rates the level of significance of the functions associated with a benefit to the overall system. To this end, all functions associated with the benefit examined are identified. Hence, all operating scenarios associated with the benefit examined are identified. For these operating scenarios, all functions which are required in the operating scenarios in question are sought. In this regard, reference is made to Fig. 6, which shows a solution structure for the vending machine described. As an addition to Fig. 4, Fig. 6 groups the functionalities 1 to 20 into the functions 1 to 7. In this context, the grouping has been carried out as follows:

   function 1 = $\{f_1, f_8, f_9, f_{10}, f_{11}, f_{13}\}$

   function 2 = $\{f_2, f_6, f_7, f_{14}\}$

   function 3 = $\{f_3\}$

   function 4 = $\{f_4\}$

   function 5 = $\{f_5\}$

function 6 = $\{f_{12}, f_{15}, f_{16}, f_{17}\}$

function 7 = $\{f_{18}, f_{19}, f_{20}\}$

By way of example, the calculation of the complexity for benefit 3 includes only the function 7, the calculation for benefit 1 includes the functions 1 to 6, and the consideration of benefit 2 includes all functions of the system. Correspondingly, the complexity of an operating scenario rates the significance of the functions used in the operating scenario.

2. Modularity:

   Modularity rates the size of the proportion of those functions in providing an examined benefit which exclusively support the examined benefit, that is to say are associated with no other benefit. The modularity of an operating scenario rates the size of the proportion of the functions used in an operating scenario which are used exclusively in this operating scenario. The solution structure shown in Fig. 6 contains modular functions for the operating scenarios 1 (functions 3, 4 and 5) and 5 (function 7). By contrast, the benefits are not modular, since each function is associated with a plurality of benefits.

3. Redundancy:

   Redundancy rates the frequency with which the specified functionality is contained in the system; the solution structure shown in Fig. 6 contains the specified functionality precisely once. If functions were present in duplicate, the redundancy of the benefits or of the operating scenarios would be greater.

4. Fault tolerance:

   Fault tolerance rates the level of dependency of the provision of a benefit or an operating scenario on a function. Full fault tolerance would exist if the function under consideration is not associated with the benefits under consideration. If there is an association, the benefit will at least be restricted if the function fails. In the example of Fig. 6, benefit 3 is 100% fault tolerant with respect to functions 1 to 6, but is not fault tolerant with respect to function 7.

5. Involvement:

   Involvement rates the significance of a function to the benefit in the system, as in the example of calculation given above.

6. Coupling and cohesion:

   Coupling and cohesion rate how closely the functionalities within a function are linked. Coupling rates how closely the functions in the system are linked.

7. Efficiency:

   Efficiency rates the level of complexity required for providing a benefit. In comparison with the significance of the benefit to the overall system.

[0050] To rate the quality of the overall system, the values ascertained by the functional metrics are combined in a weighted sum. The summands are weighted on the basis of the values ascertained in Fig. 5. Accordingly, the sum is a measure of the rating of the quality of the system.

OPTIMIZATION:

[0051] An optimization algorithm for synthesizing system structures uses the rating method described in order to search for the best possible system configuration. Taking a (any) configuration as a basis, other solutions are formed and rated at random. If the solution found is better than the previous one, it is accepted. If it is worse than the previous one, it is accepted with a degree of probability which decreases in the course of optimization. In this context, the probability of a worse solution being accepted depends not just on how far the optimization algorithm has progressed, however, but also on how seriously the value of the rating is worsened. This is intended to prevent the optimization algorithm from remaining at a local optimum. This method is also called the "simulated annealing" method.

DERIVING A FUNCTIONAL STRUCTURE

[0052] Figure 7 shows a functional structure for the vending machine. The solution structure derived from the quality demands and from the problem structure (cf. Fig. 6) serves as a basis for producing a functional network (functional structure). Preferably, the functions ascertained to be optimum, that is to say the best kind of grouping, are adopted as a functional structure. The use of functions together in an operating scenario or for a benefit results in a flow of energy, information or material, or at least a control flow, taking place between the functions directly or indirectly, that is to say via another function, in order to coordinate both functions for simultaneous or sequential use. In this context, the functions are described by the functionalities they contain. Each of the identified functions may, in turn, be considered to be a separate (sub)system. The functions can be described by new functional demands on the subsystem and can be explained in more detail using the method described.

[0053] Figure 8 shows a processor unit PRZE. The processor unit PRZE comprises a processor CPU, a memory SPE and an input/output interface IOS which is used in various ways via an interface IFC: a graphical user interface is used to visualize an output on a monitor MON and/or

to output it on a printer PRT. Input is made using a mouse MAS or a keyboard TAST. The processor unit PRZE also has a data bus BUS ensuring that a memory MEM, the processor CPU and the input/output interface IOS are connected. Additional components can also be connected to the data bus BUS, e.g. an additional memory, a data store (hard disk) or a scanner.

[0054] The invention has been described in detail with particular reference to preferred embodiments thereof and examples, but it will be understood that variations and modifications can be effected within the spirit and scope of the invention.

SUBSTITUTE ABSTRACT

METHOD, SYSTEM AND COMPUTER PROGRAM FOR DESIGNING A TECHNICAL SYSTEM

In designing a technical system where a problem structure for a technical system is prescribed, the problem structure forms a plurality of functionalities. The problem structure is rated in relation to prescribed criteria. The rating is used to group the functionalities and to design the technical system on the basis of the grouping.

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MARKED-UP SUBSTITUTE SPECIFICATION

[Description]

TITLE OF THE INVENTION

[METHOD,] SYSTEM [AND COMPUTER PROGRAM] FOR DESIGNING A TECHNICAL SYSTEM

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application is based on and hereby claims priority to German Patent Application No. 19925214.9 filed on June 1, 2001, the contents of which are hereby incorporated by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0002] The invention relates to a method, an arrangement and a computer program for designing a technical system.

2. Description of the Related Art

[0003] One aim of systems engineering is to design, simulate or lay out a technical system. In this respect, a complex technical system is usually so extensive that it is first appropriately segmented into subsystems. In this context, subdividing the overall technical system into such subsystems provides no kind of certainty that the subdivision will also furnish the appropriate (in terms of the design) subsystems. In particular, the breakdown is often performed intuitively by experts who have accumulated experience over many years. However, the complexity of the overall technical system means that there is no kind of assurance, and there is no means of causally verifying, that such intuitive breakdown of the overall technical system is particularly beneficial or even optimal.

[0004] IEEE standard 1220/1994 [(see [1])] lays down a system definition (SEP) which contains a set of rules for breaking down a complex technical system into subsystems.

[0005] A "simulated annealing" method is known from [2] Kirkpatrick, S., C.D. Gelatt Jr., M.P. Vecchi, 1983: "Optimization by Simulated Annealing", Science, V. 220, No. 4598, pp. 671-680.

SUMMARY OF THE INVENTION

[0006] The object of the invention is to provide a way of designing a technical system in which the technical system is subdivided into appropriate functionalities and hence the design of the technical system is significantly simplified. [This object is achieved on the basis of the features

of the independent patent claims. Developments of the invention can be found in the dependent claims.]

[0007] In this context, functionalities are to be understood to mean, in particular, functional units in the system, that is to say the response of the system from the point of view of a user, and also demands on functions (the system acts itself in this case).

[0008] To achieve the object, the invention specifies a method for designing a technical system in which a problem structure for a technical system is prescribed, which problem structure comprises a plurality of functionalities. The problem structure is rated in relation to prescribed criteria. The rating is used to group the functionalities and to design the technical system on the basis of the grouping.

[0009] A particular advantage in this context is that the grouping is done automatically using the rating of the problem structure on the basis of the prescribed criteria. Functionalities are thus obtained which are suited to one another particularly in respect of the design of the technical system.

[0010] One development is that the functionalities are grouped iteratively.

[0011] In this context, the problem structure may comprise not only the functionalities but also characteristic quantities providing a structure on a plurality of levels, for example operating scenarios or benefits. The functionalities may preferably have specific operating scenarios. These operating scenarios themselves have a particular benefit. The relationship between functionalities and operating scenarios can be weighted individually. The same applies for the relationship or the relation between operating scenarios and associated benefit. Another development is for the functionalities to be grouped using neural networks or using a generic algorithm.

[0012] Another development is for the grouping to be done using a "simulated annealing" method.

[0013] One refinement of the invention is that the design comprises one of the following options:

1. New design:
   New design aims to create a technical system which has preferably not existed previously in this form.

2. Adjustment:

   In the case of adjustment, an already existing technical system is preferably adapted. This can be done with regard to optimized, improved or extended parameters. Partial conversion or partial redesign of the technical system can also be regarded as adjustment.

3. Layout:

   Layout preferably relates to technical installations which, in order to meet particular technical specifications, need to have predefined dimensions, for example. Thus, for example, a factory can be laid out for producing a particular minimum quantity of a prescribed product. This minimum quantity results in specifications regarding size, number of production lines, power consumption, infrastructure etc.

4. Rating, assessment:

   The design can also be used to rate or to assess a technical system. Particularly in the case of intuitively designed technical systems, it is advantageous to find out for certain about a level of efficiency of this technical system. Such a rating is also very useful when searching for improvement potential with regard to a more economical way of working.

5. Simulation:

   The design reflected in the simulation is preferably used to present a preliminary stage for a real embodiment of the technical system. Often, the simulation can be used to determine a suitable technical system which, when produced in practice, results in high cost and therefore needs to be predefined particularly precisely and versatilely in the course of simulative planning.

6. Validation:

   The design also permits validation (inspection), on the basis of which the technical system is validated in terms of size, layout, functionality, etc. in comparison with the specifications made. The result of validation may be, by way of example, a binary decision, for example "suitable" or "not suitable".

[0014] Another refinement involves the design being used to ascertain a functional network for the technical system. The functional network is preferably suitable as a preliminary stage for the practical implementation of the technical system.

[0015] Another refinement is that the prescribed criteria comprise quality criteria.

[0016] In this context, the prescribed criteria can comprise at least one of the following options: Usability, modifiability, maintainability, checkability, portability, integrity, development complexity,

performance, reusability, reliability. Correspondingly, numerous other prescribed criteria are possible.

[0017] Another refinement is that the prescribed criteria are weighted. If, by way of example, the functionality is linked to a weighting in terms of a particular criterion (which is affected in a particular way by this functionality) allows a weighted assessment for the design, in particular when the functionalities are grouped.

[0018] The object is also achieved by specifying an arrangement for designing a technical system, which arrangement is provided with a processor unit which is set up such that

a) a problem structure for the technical system can be prescribed, which problem structure comprises (a plurality of) functionalities;

b) the problem structure can be rated on the basis of prescribed criteria;

c) the rating is used to group the functionalities;

d) the technical system can be designed on the basis of the grouping.

[0019] In addition, the object is achieved by specifying a computer program which is set up such that, when running on a processor unit, it performs the following steps:

a) a problem structure for the technical system can be prescribed, which problem structure comprises (a plurality of) functionalities;

b) the problem structure is rated on the basis of prescribed criteria;

c) the rating is used to group the functionalities;

d) the technical system is designed on the basis of the grouping.

[0020] The arrangement and the computer program are particularly suitable for implementing the inventive method or one of its developments explained above.

<u>BRIEF DESCRIPTION OF THE DRAWINGS</u>

[0021] [Exemplary] <u>These and other objects and advantages of the present invention will become more apparent and more readily appreciated from the following description of the preferred</u> embodiments of the invention are illustrated and explained below with reference to the [drawing] <u>drawings</u>, in which

Figure 1 [shows] <u>is a block diagram of</u> a multilevel problem structure;

Figure 2 [shows] <u>is a table indicating</u> an association between quality features and functional metrics;

Figure 3 [shows] is a block diagram of a solution structure in which functionalities are grouped into individual functions;

Figure 4 [shows] Figures 4A and 4B form a block diagram of one possible problem structure;

Figure 5 [shows] is a table containing weightings for the functional metrics;

[Figure 6 shows] Figures 6A and 6B form a block diagram of a solution structure for a vending machine;

Figure 7 [shows] is a block diagram of a functional network for the vending machine;

Figure 8 [shows] is a block diagram of a processor unit.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0022] Reference will now be made in detail to the preferred embodiments of the present invention, examples of which are illustrated in the accompanying drawings, wherein like reference numerals refer to like elements throughout.

[0023] Figure 1 shows a hierarchical problem structure. In this case, a hierarchical level 101 comprises a plurality of functionalities (1 to 7), a hierarchical level 102 comprises a plurality of operating scenarios (1 to 3), and a hierarchical level 103 comprises a plurality of benefits (1 and 2). Preferably, the problem structure is determined at the start from demands made on a product by a customer. The problem structure shows functionalities 101 which the customer expects from the product. The operating scenarios 102 take account of operating situations in which the customer (user) would like to use the functionalities 101 described. Finally, the hierarchical level 103 contains the benefit which the customer (user) would like to derive from the product. In the example in [Figure] Fig. 1, the functionalities required for the specific operating situation and the benefits relating to those operating scenarios in which they are to be provided are associated with the operating scenarios.

[0024] A use u_x can be agreed between individual functionalities and operating scenarios (see reference 104). In [Figure] Fig. 1, the functionality 1 has a use u_1 relating to the operating scenario 1, and a functionality 4 has a use u_4 relating to the operating scenario and a use u_6 relating to the operating scenario 2. A complete relationship between the use 104 of the individual functionalities 1 to 7 and the operating scenarios 1 to 3 is given by the following relations:

$$\text{operating scenario 1} = \{u1_{f1}, u2_{f2}, u3_{f3}, u4_{f4}\}$$

$$\text{operating scenario 2} = \{u5_{f3}, u6_{f4}, u7_{f5}, u8_{f6}\}$$

operating scenario 3 = $\{u9_{f6}, u10_{f7}\}$

In this context u_x denotes the use, with fi (i=1...7) respectively identifying the functionality 1 to 7 linked to the use.

[0025] Correspondingly, the operating scenarios 102 provide a useful contribution n_L for the benefit 103 (reference 105). In the example in [Figure] Fig. 1, the following relation is obtained:

benefit 1 = $\{n1_{B1,} n2_{B2}, n3_{B3}\}$

benefit 2 = $\{n4_{B3}\}$

Bi (i = 1 to 3) identifies the respective operating scenario providing the respective useful contribution n_L for the benefit 103 indicated above.

[0026] Figure 2 shows an association between quality features and functional metrics. The method presented here makes it possible to improve different quality features of a technical system. There are various quality features in this respect; the list below is not conclusive:

- usability
- modifiability
- maintainability
- checkability
- portability
- integrity
- development complexity
- performance
- reusability
- reliability

[0027] Depending on the respective technical system, quality features have different significance or priority. By way of example, reliability and development complexity are crucial quality features for a satellite; for durable, easily accessible products, for example an aircraft carrier or a power station, quality features such as modifiability and maintainability are of particular significance.

[0028] Figure 2 shows, in the form of a table, an example of how quality features can be shown above structural features and at what point the improvement or optimization of the technical system can take effect, individually, on the basis of prescribed functional metrics. The weighting

of the quality features for the respective technical system is used to derive a profile of structural features, which profile will be rated in detail by functional metrics.

[0029] Figure 3 shows a solution structure in which functionalities have been grouped into individual functions. The problem structure from [Figure] Fig. 1 and the weighting of the quality demands on the product from [Figure] Fig. 2 are used as a basis for determining a solution structure (a combination of functionalities into functions). Each function, that is to say each group of functionalities, describes a response from a subsystem, in particular from an advantageously determinable part of the overall technical system. In this context, the groups are determined such that structural features derived from the quality features take the best possible form. In [Figure] Fig. 3, functionalities 1 and 2 have been combined to give a function 1, functionalities 3 to 5 have been combined to give a function 2 and functionalities 6 and 7 have been combined to give a function 3.

[0030] The weighted quality features are used to derive a weighting for the functional metrics. The structural features of the solution are rated on the basis of the functional metrics. The structural features which are to be rated on the basis of the functional metrics are described individually below:

1. Complexity:
   The complexity rates the level of significance of the function associated with a benefit or an operating scenario to the overall system.

2. Modularity:
   Modularity assesses the size of the proportion of those functions in a benefit or in an operating scenario which are exclusively associated with the benefit or operating scenario under consideration.

3. Redundancy:
   Redundancy rates whether a function is contained in duplicate or a plurality of times in the system.

4. Involvement:
   Involvement rates the significance of a function to the overall system.

5. Coupling:
   Coupling rates how closely the functions in the system are linked to one another.

6. Cohesion:

   Cohesion rates the strength of the internal link for a function.

7. Efficiency:

   Efficiency rates the level of complexity for providing a benefit or an operating scenario in relation to the significance of the benefit to the overall system.

OPTIMIZATION:

[0031] A solution is chosen which serves as a starting point for an optimization algorithm. This solution is rated by the previously weighted functional metrics. This weighting and the results of the rating of the structural features are then used to ascertain an overall rating. This overall rating shows how well the system structure under consideration meets the quality demands made.

[0032] Taking the initial configuration as a basis, the optimization algorithm is used to determine and rate new functions (or groups of functionalities). The optimization algorithm preferably searches for alternative solution structures until a suitable configuration has been found.

OUTPUT:

[0033] The method described is preferably suitable for automatically deriving suitable structures from demands on a technical system. In this context, the solution structure serves as a basis for determining a functional network in which the interfaces between the functions are stipulated on the basis of the solution structure. The dependencies between the functions to be provided are ascertained by providing a rating for whether functions are used together in particular situations or for particular purposes: their use together implies, by way of example, flows of energy, material or information between the functions, or at least a control flow which controls the use of the functions together.

[0034] If the data are conditioned appropriately, already existing architectures can be rated, assessed, validated, simulated and improved.

[0035] The functional metrics can also be used to check the fundamental structure, for example to determine whether the envisaged response and use of the product are at all able to meet prescribed quality demands, or whether, instead, the problem structure itself still requires further improvements (for example addition of redundancies, decoupling of individual operating states).

EXAMPLE

[0036] The method described above is explained below with the aid of a vending machine (for example for confectionery, cigarettes or drinks).

Problem structure:

[0037] First, the demands on the product are modeled in the problem structure. Figure 4 shows one possible problem structure:

a) An operator of the vending machine wishes to provide various benefits by operating the vending machine. Firstly, he wants to make a profit by selling the products he offers and by collecting the resultant proceeds of the sale, and secondly, by varying the products offered, he wants to ensure that he can always satisfy the requirements of his customers as well as possible.

b) These benefits are provided by the machine in various operating situations: firstly, the machine accepts money from the customer and then allows him to select one of the products offered. After the selection has been made, the appropriate product is dispensed, if appropriate together with change. From time to time, the vending machine needs maintaining, in the course of which the products offered can be replaced and the collected proceeds of sale are removed from the machine.

c) In the individual operating situations, the machine needs to respond in accordance with a product specification. This response is described by the functionalities 401 (numbered 1 to 20). The functionalities firstly describe the modes of behavior required in the respective operating situation and secondly also the state conditions for changing between two operating situations.

[0038] Figure 4 also shows that the associations between the individual elements (functionalities, operating scenarios and benefits) of the problem structure can be weighted. Alternatively, the method can also be applied to unweighted problem structures. Weighting is used to give a more precise description of the structure of the elements in relation to one another; important features of the problem structure are preferably defined by the presence or absence of the associations.

[0039] Information required for producing the problem structure can frequently be taken from the product specification. The problem structure reflects the customer's ideas about the response of the product without taking into account possible technical implementations. Besides the functionalities 401, [Figure] <u>Fig.</u> 4 shows operating scenarios 402 (numbered 1 to 5)

and benefits 403 (numbered 1 to 3). There is also a link between individual functionalities and particular operating scenarios, summarized as use 404. A corresponding relation between individual operating scenarios and individual benefits is shown in [Figure] Fig. 4 as a useful contribution 405. The individual associations 404 and 405 are weighted, as described above.

QUALITY FEATURES:

[0040] The vending machine to be developed (see above) has various demands made on it in the course of its life cycle. Since the vending machine is produced in large numbers, a development phase takes on rather low significance. This means that rather low significance is attached to the quality features "development complexity", "checkability" (testability of the individual modules during the development and production phase) and "reusability" (use of commercially available/already developed assemblies for the vending machine system). In the example, the quality features together have the weighting 0.25 (cf. top row in [Figure] Fig. 5). By contrast, the operating phase in the product life cycle is much more significant to the success of the product "vending machine". In this case, the relevant quality features are "usability" from the point of view of the customer, and "maintainability", "modifiability" and "reliability" from the point of view of the machine operator. The weighting for these quality features prescribed by the operation of the vending machine is 0.75 (cf. first row in [Figure] Fig. 5 in this case too). The sum of all the weightings for all the quality features has been normalized to 1 in the example. The association matrix 503 is used to calculate the weighting factors 502 for the functional metrics from the weightings 501. In this context, the weighting for a functional metric $g(F_j)$ is the sum of the product of the association matrix Z_{ij}, the weighting factor w_i and the weighting $g(Q_i)$ for all i when j = constant.

[0041] Note: Z_{ij} is an element in the association matrix, w_i is the weighting factor for the product and $g(Q_i)$ is the weighting for a quality feature.

[0042] The following is obtained:

$$g(F_j) = \Sigma_i (Z_{ij} * g(Q_i) * w_i).$$

[0043] As stated above, the sum of the weightings for the quality features and the weightings for the functional metrics is preferably equal to 1.

[0044] The result of a weighting determined in this way is that an overall weighting can be calculated which is used to indicate the extent to which the solution structure determined for the technical system covers particular quality demands.

RATING:

[0045] The functional metrics rate the type and "strength" of the links between the individual elements of the solution structure. Hence, not just the links between the elements of the structure are taken into consideration, but also which of the functionalities are combined to give a function (grouping!).

CALCULATION EXAMPLE (SEE [FIGURE] FIG. 4):

[0046] The strength of the link between the functionality "1. Coins from customer are accepted as payment" and the benefit "1. Sale of the product selected by the customer" is

$$0.1 * 0.25 = 0.025$$

[0047] The significance of the functionality to the overall system is calculated on the basis of the link to the overall system benefit, in which the benefits 1, 2 and 3 each have the proportion 0.33: besides the link just described relating to operating scenario 1 and benefit 1, the links via operating scenario 2 to benefit 1 and via operating scenario 1 to benefit 2 also contribute to the significance of the functionality. This significance of the functionality is calculated as the sum of the three associations:

$$0.1 * 0.25 * 0.33 + 0.1 * 0.33 * 0.33 [+] + 0.2 * 0.25 * 0.33 = 0.03564$$

[0048] If the significance of functions is calculated as groups of functionalities for the overall system, the significances of the individual functionalities contained in the group are added.

[0049] This described method of calculation is used for the different functional metrics in order to rate different properties of the system. Specifically, the procedure for calculating the various values is as follows:

1. Complexity:
   Complexity rates the level of significance of the functions associated with a benefit to the overall system. To this end, all functions associated with the benefit examined are identified. Hence, all operating scenarios associated with the benefit examined are identified. For these operating scenarios, all functions which are required in the operating scenarios in question are sought. In this regard, reference is made to [Figure] Fig. 6, which shows a solution structure for the vending machine described. As an addition to [Figure] Fig. 4, [Figure] Fig. 6 groups the functionalities 1 to 20 into the functions 1 to 7. In this context, the grouping has been carried out as follows:

   function 1 = $\{f_1, f_8, f_9, f_{10}, f_{11}, f_{13}\}$

function 2 = {f_2, f_6, f_7, f_{14}}

function 3 = {f_3}

function 4 = {f_4}

function 5 = {f_5}

function 6 = {f_{12}, f_{15}, f_{16}, f_{17}}

function 7 = {f_{18}, f_{19}, f_{20}}

By way of example, the calculation of the complexity for benefit 3 includes only the function 7, the calculation for benefit 1 includes the functions 1 to 6, and the consideration of benefit 2 includes all functions of the system. Correspondingly, the complexity of an operating scenario rates the significance of the functions used in the operating scenario.

2. Modularity:

   Modularity rates the size of the proportion of those functions in providing an examined benefit which exclusively support the examined benefit, that is to say are associated with no other benefit. The modularity of an operating scenario rates the size of the proportion of the functions used in an operating scenario which are used exclusively in this operating scenario. The solution structure shown in [Figure] Fig. 6 contains modular functions for the operating scenarios 1 (functions 3, 4 and 5) and 5 (function 7). By contrast, the benefits are not modular, since each function is associated with a plurality of benefits.

3. Redundancy:

   Redundancy rates the frequency with which the specified functionality is contained in the system; the solution structure shown in [Figure] Fig. 6 contains the specified functionality precisely once. If functions were present in duplicate, the redundancy of the benefits or of the operating scenarios would be greater.

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   Fault tolerance rates the level of dependency of the provision of a benefit or an operating scenario on a function. Full fault tolerance would exist if the function under consideration is not associated with the benefits under consideration. If there is an association, the benefit will at least be restricted if the function fails. In the example of [Figure] Fig. 6, benefit 3 is 100% fault tolerant with respect to functions 1 to 6, but is not fault tolerant with respect to function 7.

5. Involvement:

   Involvement rates the significance of a function to the benefit in the system, as in the example of calculation given above.

6. Coupling and cohesion:

   Coupling and cohesion rate how closely the functionalities within a function are linked. Coupling rates how closely the functions in the system are linked.

7. Efficiency:

   Efficiency rates the level of complexity required for providing a benefit. In comparison with the significance of the benefit to the overall system.

[0050] To rate the quality of the overall system, the values ascertained by the functional metrics are combined in a weighted sum. The summands are weighted on the basis of the values ascertained in [Figure] Fig. 5. Accordingly, the sum is a measure of the rating of the quality of the system.

OPTIMIZATION:

[0051] An optimization algorithm for synthesizing system structures uses the rating method described in order to search for the best possible system configuration. Taking a (any) configuration as a basis, other solutions are formed and rated at random. If the solution found is better than the previous one, it is accepted. If it is worse than the previous one, it is accepted with a degree of probability which decreases in the course of optimization. In this context, the probability of a worse solution being accepted depends not just on how far the optimization algorithm has progressed, however, but also on how seriously the value of the rating is worsened. This is intended to prevent the optimization algorithm from remaining at a local optimum. This method is also called the "simulated annealing" method.

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they contain. Each of the identified functions may, in turn, be considered to be a separate (sub)system. The functions can be described by new functional demands on the subsystem and can be explained in more detail using the method described.

[0053] Figure 8 shows a processor unit PRZE. The processor unit PRZE comprises a processor CPU, a memory SPE and an input/output interface IOS which is used in various ways via an interface IFC: a graphical user interface is used to visualize an output on a monitor MON and/or to output it on a printer PRT. Input is made using a mouse MAS or a keyboard TAST. The processor unit PRZE also has a data bus BUS ensuring that a memory MEM, the processor CPU and the input/output interface IOS are connected. Additional components can also be connected to the data bus BUS, e.g. an additional memory, a data store (hard disk) or a scanner.

[0054] The invention has been described in detail with particular reference to preferred embodiments thereof and examples, but it will be understood that variations and modifications can be effected within the spirit and scope of the invention.

[Bibliography:]

[1] [IEEE Standard 1220/94]

[2] [Kirkpatrick, S., C.D. Gelatt Jr., M.P. Vecchi, 1983: “Optimization by Simulated Annealing”, Science, V. 220, No. 4598, pp. 671-680.]

Description

Method, arrangement and computer program for designing a technical system

The invention relates to a method, an arrangement and a computer program for designing a technical system.

One aim of systems engineering is to design, simulate or lay out a technical system. In this respect, a complex technical system is usually so extensive that it is first appropriately segmented into subsystems. In this context, subdividing the overall technical system into such subsystems provides no kind of certainty that the subdivision will also furnish the appropriate (in terms of the design) subsystems. In particular, the breakdown is often performed intuitively by experts who have accumulated experience over many years. However, the complexity of the overall technical system means that there is no kind of assurance, and there is no means of causally verifying, that such intuitive breakdown of the overall technical system is particularly beneficial or even optimal.

IEEE standard 1220/1994 (see [1]) lays down a system definition (SEP) which contains a set of rules for breaking down a complex technical system into subsystems.

A "simulated annealing" method is known from [2].

The object of the invention is to provide a way of designing a technical system in which the technical system is subdivided into appropriate functionalities and hence the design of the technical system is significantly simplified.

This object is achieved on the basis of the features of the independent patent claims. Developments of the invention can be found in the dependent claims.

In this context, functionalities are to be understood to mean, in particular, functional units in the system, that is to say the response of the system from the point of view of a user, and also demands on functions (the system acts itself in this case).

To achieve the object, the invention specifies a method for designing a technical system in which a problem structure for a technical system is prescribed, which problem structure comprises a plurality of functionalities. The problem structure is rated in relation to prescribed criteria. The rating is used to group the functionalities and to design the technical system on the basis of the grouping.

A particular advantage in this context is that the grouping is done automatically using the rating of the problem structure on the basis of the prescribed criteria. Functionalities are thus obtained which are suited to one another particularly in respect of the design of the technical system.

One development is that the functionalities are grouped iteratively.

In this context, the problem structure may comprise not only the functionalities but also characteristic quantities providing a structure on a plurality of levels, for example operating scenarios or benefits. The functionalities may preferably have specific operating scenarios. These operating scenarios themselves have a particular benefit. The relationship between functionalities and operating scenarios can be weighted individually. The same applies for the

relationship or the relation between operating scenarios and associated benefit.

Another development is for the functionalities to be grouped using neural networks or using a generic algorithm.

Another development is for the grouping to be done using a "simulated annealing" method.

One refinement of the invention is that the design comprises one of the following options:

1. New design:
   New design aims to create a technical system which has preferably not existed previously in this form.

2. Adjustment:
   In the case of adjustment, an already existing technical system is preferably adapted. This can be done with regard to optimized, improved or extended parameters. Partial conversion or partial redesign of the technical system can also be regarded as adjustment.

3. Layout:
   Layout preferably relates to technical installations which, in order to meet particular technical specifications, need to have predefined dimensions, for example. Thus, for example, a factory can be laid out for producing a particular minimum quantity of a prescribed product. This minimum quantity results in specifications regarding size, number of production lines, power consumption, infrastructure etc.

4. Rating, assessment:
   The design can also be used to rate or to assess a technical system. Particularly in the case of

intuitively designed technical systems, it is advantageous to find out for certain about a level of efficiency of this technical system. Such a rating is also very useful when searching for improvement potential with regard to a more economical way of working.

5. Simulation:
The design reflected in the simulation is preferably used to present a preliminary stage for a real embodiment of the technical system. Often, the simulation can be used to determine a suitable technical system which, when produced in practice, results in high cost and therefore needs to be predefined particularly precisely and versatilely in the course of simulative planning.

6. Validation:
The design also permits validation (inspection), on the basis of which the technical system is validated in terms of size, layout, functionality, etc. in comparison with the specifications made. The result of validation may be, by way of example, a binary decision, for example "suitable" or "not suitable".

Another refinement involves the design being used to ascertain a functional network for the technical system. The functional network is preferably suitable as a preliminary stage for the practical implementation of the technical system.

Another refinement is that the prescribed criteria comprise quality criteria.

In this context, the prescribed criteria can comprise at least one of the following options:

Usability, modifiability, maintainability, checkability, portability, integrity, development complexity,

performance, reusability, reliability. Correspondingly, numerous other prescribed criteria are possible.

Another refinement is that the prescribed criteria are weighted. If, by way of example, the functionality is linked to a weighting in terms of a particular criterion (which is affected in a particular way by this functionality) allows a weighted assessment for the design, in particular when the functionalities are grouped.

The object is also achieved by specifying an arrangement for designing a technical system, which arrangement is provided with a processor unit which is set up such that

a) a problem structure for the technical system can be prescribed, which problem structure comprises (a plurality of) functionalities;
b) the problem structure can be rated on the basis of prescribed criteria;
c) the rating is used to group the functionalities;
d) the technical system can be designed on the basis of the grouping.

In addition, the object is achieved by specifying a computer program which is set up such that, when running on a processor unit, it performs the following steps:

a) a problem structure for the technical system can be prescribed, which problem structure comprises (a plurality of) functionalities;
b) the problem structure is rated on the basis of prescribed criteria;
c) the rating is used to group the functionalities;
d) the technical system is designed on the basis of the grouping.

The arrangement and the computer program are particularly suitable for implementing the inventive method or one of its developments explained above.

Exemplary embodiments of the invention are illustrated and explained below with reference to the drawing, in which

figure 1 shows a multilevel problem structure;

figure 2 shows an association between quality features and functional metrics;

figure 3 shows a solution structure in which functionalities are grouped into individual functions;

figure 4 shows one possible problem structure;

figure 5 shows a table containing weightings for the functional metrics;

figure 6 shows a solution structure for a vending machine;

figure 7 shows a functional network for the vending machine;

figure 8 shows a processor unit.

Figure 1 shows a hierarchical problem structure. In this case, a hierarchical level 101 comprises a plurality of functionalities (1 to 7), a hierarchical level 102 comprises a plurality of operating scenarios (1 to 3), and a hierarchical level 103 comprises a plurality of benefits (1 and 2). Preferably, the problem structure is determined at the start from demands made on a product by a customer. The problem

structure shows functionalities 101 which the customer expects from the product. The operating scenarios 102 take account of operating

situations in which the customer (user) would like to use the functionalities 101 described. Finally, the hierarchical level 103 contains the benefit which the customer (user) would like to derive from the product. In the example in figure 1, the functionalities required for the specific operating situation and the benefits relating to those operating scenarios in which they are to be provided are associated with the operating scenarios.

A use u_x can be agreed between individual functionalities and operating scenarios (see reference 104). In figure 1, the functionality 1 has a use u_1 relating to the operating scenario 1, and a functionality 4 has a use u_4 relating to the operating scenario and a use u_6 relating to the operating scenario 2. A complete relationship between the use 104 of the individual functionalities 1 to 7 and the operating scenarios 1 to 3 is given by the following relations:

operating scenario 1 = $\{u1_{f1},\ u2_{f2},\ u3_{f3},\ u4_{f4}\}$

operating scenario 2 = $\{u5_{f3},\ u6_{f4},\ u7_{f5},\ u8_{f6}\}$

operating scenario 3 = $\{u9_{f6},\ u10_{f7}\}$

In this context u_x denotes the use, with fi (i=1…7) respectively identifying the functionality 1 to 7 linked to the use.

Correspondingly, the operating scenarios 102 provide a useful contribution n_L for the benefit 103 (reference 105). In the example in figure 1, the following relation is obtained:

benefit 1 = $\{n1_{B1,}\ n2_{B2},\ n3_{B3}\}$
benefit 2 = $\{n4_{B3}\}$

Bi (i = 1 to 3) identifies the respective operating scenario providing the respective useful contribution n_L for the benefit 103 indicated above.

Figure 2 shows an association between quality features and functional metrics. The method presented here makes it possible to improve different quality features of a technical system. There are various quality features in this respect; the list below is not conclusive:

- usability
- modifiability
- maintainability
- checkability
- portability
- integrity
- development complexity
- performance
- reusability
- reliability

Depending on the respective technical system, quality features have different significance or priority. By way of example, reliability and development complexity are crucial quality features for a satellite; for durable, easily accessible products, for example an aircraft carrier or a power station, quality features such as modifiability and maintainability are of particular significance.

Figure 2 shows, in the form of a table, an example of how quality features can be shown above structural features and at what point the improvement or optimization of the technical system can take effect, individually, on the basis of prescribed functional metrics. The weighting of the quality features for the respective technical system is used to derive a profile of

structural features, which profile will be rated in detail by functional metrics.

Figure 3 shows a solution structure in which functionalities have been grouped into individual functions. The problem structure from figure 1 and the weighting of the quality demands on the product from figure 2 are used as a basis for determining a solution structure (a combination of functionalities into functions). Each function, that is to say each group of functionalities, describes a response from a subsystem, in particular from an advantageously determinable part of the overall technical system. In this context, the groups are determined such that structural features derived from the quality features take the best possible form. In figure 3, functionalities 1 and 2 have been combined to give a function 1, functionalities 3 to 5 have been combined to give a function 2 and functionalities 6 and 7 have been combined to give a function 3.

The weighted quality features are used to derive a weighting for the functional metrics. The structural features of the solution are rated on the basis of the functional metrics. The structural features which are to be rated on the basis of the functional metrics are described individually below:

1. Complexity:

   The complexity rates the level of significance of the function associated with a benefit or an operating scenario to the overall system.

2. Modularity:

   Modularity assesses the size of the proportion of those functions in a benefit or in an operating scenario which are exclusively associated with the benefit or operating scenario under consideration.

3. Redundancy:

Redundancy rates whether a function is contained in duplicate or

a plurality of times in the system.

4. Involvement:
Involvement rates the significance of a function to the overall system.

5. Coupling:
Coupling rates how closely the functions in the system are linked to one another.

6. Cohesion:
Cohesion rates the strength of the internal link for a function.

7. Efficiency:
Efficiency rates the level of complexity for providing a benefit or an operating scenario in relation to the significance of the benefit to the overall system.

OPTIMIZATION:

A solution is chosen which serves as a starting point for an optimization algorithm. This solution is rated by the previously weighted functional metrics. This weighting and the results of the rating of the structural features are then used to ascertain an overall rating. This overall rating shows how well the system structure under consideration meets the quality demands made.

Taking the initial configuration as a basis, the optimization algorithm is used to determine and rate new functions (or groups of functionalities). The optimization algorithm preferably searches for alternative solution structures until a suitable configuration has been found.

OUTPUT:

The method described is preferably suitable for automatically deriving suitable structures from demands on a technical system. In this context, the solution structure serves as a basis for determining a functional network in which the interfaces between the functions are stipulated on the basis of the solution structure. The dependencies between the functions to be provided are ascertained by providing a rating for whether functions are used together in particular situations or for particular purposes: their use together implies, by way of example, flows of energy, material or information between the functions, or at least a control flow which controls the use of the functions together.

If the data are conditioned appropriately, already existing architectures can be rated, assessed, validated, simulated and improved.

The functional metrics can also be used to check the fundamental structure, for example to determine whether the envisaged response and use of the product are at all able to meet prescribed quality demands, or whether, instead, the problem structure itself still requires further improvements (for example addition of redundancies, decoupling of individual operating states).

EXAMPLE

The method described above is explained below with the aid of a vending machine (for example for confectionery, cigarettes or drinks).

Problem structure:

First, the demands on the product are modeled in the problem structure. Figure 4 shows one possible problem structure:

a) An operator of the vending machine wishes to provide various benefits by operating the vending machine. Firstly, he wants to make a profit by selling the products he offers and by collecting the resultant proceeds of the sale, and secondly, by varying the products offered, he wants to ensure that he can always satisfy the requirements of his customers as well as possible.

b) These benefits are provided by the machine in various operating situations: firstly, the machine accepts money from the customer and then allows him to select one of the products offered. After the selection has been made, the appropriate product is dispensed, if appropriate together with change. From time to time, the vending machine needs maintaining, in the course of which the products offered can be replaced and the collected proceeds of sale are removed from the machine.

c) In the individual operating situations, the machine needs to respond in accordance with a product specification. This response is described by the functionalities 401 (numbered 1 to 20). The functionalities firstly describe the modes of behavior required in the respective operating situation and secondly also the state conditions for changing between two operating situations.

Figure 4 also shows that the associations between the individual elements (functionalities, operating scenarios and benefits) of the problem structure can be weighted. Alternatively, the method can also be applied to unweighted problem structures. Weighting is used to give a more precise description of the structure of the elements in relation to one another; important features of the problem structure are preferably defined by the presence or absence of the associations.

Information required for producing the problem structure can frequently be taken from the product specification. The problem structure reflects the customer's ideas about the response of the product without taking into account possible technical implementations. Besides the functionalities 401, figure 4 shows operating scenarios 402 (numbered 1 to 5) and benefits 403 (numbered 1 to 3). There is also a link between individual functionalities and particular operating scenarios, summarized as use 404. A corresponding relation between individual operating scenarios and individual benefits is shown in figure 4 as a useful contribution 405. The individual associations 404 and 405 are weighted, as described above.

QUALITY FEATURES:

The vending machine to be developed (see above) has various demands made on it in the course of its life cycle. Since the vending machine is produced in large numbers, a development phase takes on rather low significance. This means that rather low significance is attached to the quality features "development complexity", "checkability" (testability of the individual modules during the development and production phase) and "reusability" (use of commercially available/already developed assemblies for the vending machine system). In the example, the quality features together have the weighting 0.25 (cf. top row in figure 5). By contrast, the operating phase in the product life cycle is much more significant to the success of the product "vending machine". In this case, the relevant quality features are "usability" from the point of view of the customer, and "maintainability", "modifiability" and "reliability" from the point of view of the machine operator. The weighting for these quality features prescribed by the operation of the vending machine is 0.75 (cf. first row

in figure 5 in this case too). The sum of all the weightings for all the quality features has been normalized to 1 in the example. The association matrix 503 is used to calculate the weighting factors 502 for the functional metrics

from the weightings 501. In this context, the weighting for a functional metric $g(F_j)$ is the sum of the product of the association matrix Z_{ij}, the weighting factor w_i and the weighting $g(Q_i)$ for all i when j = constant.

Note: Z_{ij} is an element in the association matrix, w_i is the weighting factor for the product and $g(Q_i)$ is the weighting for a quality feature.

The following is obtained:

$$g(F_j) = \Sigma_i \ (Z_{ij} * g \ (Q_i) * w_i).$$

As stated above, the sum of the weightings for the quality features and the weightings for the functional metrics is preferably equal to 1.

The result of a weighting determined in this way is that an overall weighting can be calculated which is used to indicate the extent to which the solution structure determined for the technical system covers particular quality demands.

RATING:

The functional metrics rate the type and "strength" of the links between the individual elements of the solution structure. Hence, not just the links between the elements of the structure are taken into consideration, but also which of the functionalities are combined to give a function (grouping!).

CALCULATION EXAMPLE (SEE FIGURE 4):

The strength of the link between the functionality "1. Coins from customer are accepted as payment" and the benefit "1. Sale of the product selected by the customer" is

$$0.1 * 0.25 = 0.025$$

The significance of the functionality to the overall system is calculated on the basis of the link to the overall system benefit, in which the benefits 1, 2 and 3 each have the proportion 0.33: besides the link just described relating to operating scenario 1 and benefit 1, the links via operating scenario 2 to benefit 1 and via operating scenario 1 to benefit 2 also contribute to the significance of the functionality. This significance of the functionality is calculated as the sum of the three associations:

$$0.1 * 0.25 * 0.33 + 0.1 * 0.33 * 0.33 + \\ + 0.2 * 0.25 * 0.33 = 0.03564$$

If the significance of functions is calculated as groups of functionalities for the overall system, the significances of the individual functionalities contained in the group are added.

This described method of calculation is used for the different functional metrics in order to rate different properties of the system. Specifically, the procedure for calculating the various values is as follows:

1. Complexity:
   Complexity rates the level of significance of the functions associated with a benefit to the overall system. To this end, all functions associated with the benefit examined are identified. Hence, all operating scenarios associated with the benefit examined are identified. For these operating scenarios, all functions which are required in the operating scenarios in question are sought. In this regard, reference is made to figure 6, which shows a solution structure for the vending machine described. As an addition to figure 4, figure 6 groups the functionalities 1 to 20 into

the functions 1 to 7. In this context, the grouping has been carried out as follows:

function 1 = $\{f_1, f_8, f_9, f_{10}, f_{11}, f_{13}\}$

function 2 = $\{f_2, f_6, f_7, f_{14}\}$

function 3 = $\{f_3\}$

function 4 = $\{f_4\}$

function 5 = $\{f_5\}$

function 6 = $\{f_{12}, f_{15}, f_{16}, f_{17}\}$

function 7 = $\{f_{18}, f_{19}, f_{20}\}$

By way of example, the calculation of the complexity for benefit 3 includes only the function 7, the calculation for benefit 1 includes the functions 1 to 6, and the consideration of benefit 2 includes all functions of the system.

Correspondingly, the complexity of an operating scenario rates the significance of the functions used in the operating scenario.

2. Modularity:

Modularity rates the size of the proportion of those functions in providing an examined benefit which exclusively support the examined benefit, that is to say are associated with no other benefit. The modularity of an operating scenario rates the size of the proportion of the functions used in an operating scenario which are used exclusively in this operating scenario. The solution structure shown in figure 6 contains modular functions for the operating scenarios 1 (functions 3, 4 and 5) and 5 (function 7). By contrast, the benefits

are not modular, since each function is associated with a plurality of benefits.

3. Redundancy:
Redundancy rates the frequency with which the specified functionality is contained in the system; the solution structure shown in figure 6 contains the specified functionality precisely once. If functions were present in duplicate, the redundancy of the benefits or of the operating scenarios would be greater.

4. Fault tolerance:
Fault tolerance rates the level of dependency of the provision of a benefit or an operating scenario on a function. Full fault tolerance would exist if the function under consideration is not associated with the benefits under consideration. If there is an association, the benefit will at least be restricted if the function fails. In the example of figure 6, benefit 3 is 100% fault tolerant with respect to functions 1 to 6, but is not fault tolerant with respect to function 7.

5. Involvement:
Involvement rates the significance of a function to the benefit in the system, as in the example of calculation given above.

6. Coupling and cohesion:
Coupling and cohesion rate how closely the functionalities within a function are linked. Coupling rates how closely the functions in the system are linked.

7. Efficiency:
Efficiency rates the level of complexity required for providing a benefit. In comparison

with the significance of the benefit to the overall system.

To rate the quality of the overall system, the values ascertained by the functional metrics are combined in a weighted sum. The summands are weighted on the basis of the values ascertained in figure 5. Accordingly, the sum is a measure of the rating of the quality of the system.

OPTIMIZATION:

An optimization algorithm for synthesizing system structures uses the rating method described in order to search for the best possible system configuration. Taking a (any) configuration as a basis, other solutions are formed and rated at random. If the solution found is better than the previous one, it is accepted. If it is worse than the previous one, it is accepted with a degree of probability which decreases in the course of optimization. In this context, the probability of a worse solution being accepted depends not just on how far the optimization algorithm has progressed, however, but also on how seriously the value of the rating is worsened. This is intended to prevent the optimization algorithm from remaining at a local optimum. This method is also called the "simulated annealing" method.

DERIVING A FUNCTIONAL STRUCTURE

Figure 7 shows a functional structure for the vending machine. The solution structure derived from the quality demands and from the problem structure (cf. figure 6) serves as a basis for producing a functional network (functional structure). Preferably, the functions ascertained to be optimum, that is to say the best kind of grouping, are adopted as a functional structure. The use of functions together in an operating scenario or for a benefit results in a flow of energy, information or material, or at least a control flow,

taking place between the functions directly or indirectly, that is to say via another function, in order to coordinate both functions for simultaneous or sequential use. In this context, the functions are described by the functionalities they contain. Each of the identified functions may, in turn, be considered to be a separate (sub)system. The functions can be described by new functional demands on the subsystem and can be explained in more detail using the method described.

Figure 8 shows a processor unit PRZE. The processor unit PRZE comprises a processor CPU, a memory SPE and an input/output interface IOS which is used in various ways via an interface IFC: a graphical user interface is used to visualize an output on a monitor MON and/or to output it on a printer PRT. Input is made using a mouse MAS or a keyboard TAST. The processor unit PRZE also has a data bus BUS ensuring that a memory MEM, the processor CPU and the input/output interface IOS are connected. Additional components can also be connected to the data bus BUS, e.g. an additional memory, a data store (hard disk) or a scanner.

Bibliography:

[1] IEEE Standard 1220/94

[2] Kirkpatrick, S., C.D. Gelatt Jr., M.P. Vecchi, 1983: "Optimization by Simulated Annealing", Science, V. 220, No. 4598, pp. 671-680.

Patent claims

1. A method for designing a technical system,
   a) in which a problem structure for the technical system is prescribed, which problem structure comprises (a plurality of) functionalities;
   b) in which the problem structure is rated on the basis of prescribed criteria;
   c) in which the rating is used to group the functionalities;
   d) in which the technical system is designed on the basis of the grouping.

2. The method as claimed in claim 1, in which the functionalities are grouped iteratively.

3. The method as claimed in claim 1 or 2, in which the functionalities are grouped using neural networks or genetic algorithms.

4. The method as claimed in one of the preceding claims, in which the grouping is done using a "simulated annealing" method.

5. The method as claimed in one of the preceding claims, in which the design of the technical system comprises at least one of the following options:
   a) new design;
   b) adjustment;
   c) layout;
   d) rating, assessment;
   e) simulation;
   f) validation (inspection).

6. The method as claimed in one of the preceding claims,
in which the design is used to ascertain a functional network for the technical system.

7. The method as claimed in one of the preceding claims,
in which the prescribed criteria are quality criteria.

8. The method as claimed in one of the preceding claims,
in which the prescribed criteria comprise at least one of the following options:
a) usability;
b) modifiability;
c) maintainability;
d) checkability;
e) portability;
f) integrity;
g) development complexity;
h) performance;
i) reusability;
j) reliability.

9. The method as claimed in one of the preceding claims,
in which the prescribed criteria are weighted.

10. The method as claimed in one of the preceding claims,
in which the problem structure is in a form such that the functionalities affect operating scenarios, and the operating scenarios in turn affect at least one benefit.

11. An arrangement for designing a technical system, which system is provided with a processor unit

which is set up such that

a) a problem structure for the technical system can be prescribed, which problem structure comprises (a plurality of) functionalities;

b) the problem structure can be rated on the basis of prescribed criteria;

c) the rating is used to group the functionalities;

d) the technical system can be designed on the basis of the grouping.

12. A computer program for designing a technical system, which, when running on a processor unit, processes the following steps:

a) a problem structure for the technical system can be prescribed, which problem structure comprises (a plurality of) functionalities;

b) the problem structure is rated on the basis of prescribed criteria;

c) the rating is used to group the functionalities;

d) the technical system is designed on the basis of the grouping.

GR 99 P 1958

Abstract

Method, arrangement and computer program for designing a technical system

The invention specifies a method for designing a technical system, in which a problem structure for a technical system is prescribed, which problem structure comprises a plurality of functionalities. The problem structure is rated in relation to prescribed criteria. The rating is used to group the functionalities and to design the technical system on the basis of the grouping.

[Key to figures]

Figure 1

1 = Functionality
2 = Operating scenario
3 = Benefit
4 = Useful contribution
5 = Use

Figure 2

1 = Quality features
2 = Structural features
3 = Functional metrics
4 = Usability
5 = Modifiability
6 = Maintainability
7 = Checkability
8 = Portability
9 = Integrity
10 = Development complexity
11 = Performance
12 = Reusability
13 = Reliability
14 = Complexity
15 = Functional complexity FC
16 = Functional complexity of an operating scenario
17 = Modularity
18 = Functional modularity
19 = Functional modularity of an operating scenario
20 = Redundancy
21 = Functional redundancy
22 = Fault tolerance
23 = Functional fault tolerance FT
24 = Involvement
25 = Functional involvement
26 = Coupling and cohesion
27 = Cohesion (CH)
28 = Coupling (CP)

29 = Efficiency

30 = Functional efficiency

31 = x… in relation to external resources

Figure 3

1 = Function

2 = Functionality

3 = Operating scenario

4 = Benefit

Figure 4a

1. Coins from customer are accepted as payment for the purchase.
2. All coins are checked to determine whether they are genuine.
3. Acceptance of one sent coins.
4. Acceptance of ten sent coins.
5. Acceptance of twenty sent coins.
6. All other coins are returned to the customer.
7. All coins which are not genuine are returned to the customer.
8. Product selection can be started only by a genuine coin.
9. Accept product selection from customer.
10. Check whether the selected product is available.
11. Dispense goods if sufficient money has been inserted and the product is available.
12. If payment is too much, change is given as appropriate.
13. After goods have been dispensed, selection mode is disabled until genuine coins are inserted.
14. Coins received are used as change.
15. If the product is not available, the money already paid is returned.
16. The money needs to be returned at the request of the customer.
17. The money is returned to the customer if he makes no selection.

18. During maintenance, the product prices need to be alterable.
19. The products offered should be alterable from time to time.
20. Collected proceeds of sale are removed during maintenance.

, → .

[402]

1. Accept payments.
2. Select product.
3. Dispense product.
4. Return money.
5. Maintenance of machine.

Figure 4b

1. Sale of the product selected by the customer.
2. Collection of the proceeds of sale.
3. Provision of an up-to-date product selection.

, → .

Figure 5

1 = Weighting $g(Q_i)$
2 = Total:
3 = Quality features (Q_i)
4 = Usability
5 = Modifiability
6 = Maintainability
7 = Checkability
8 = Portability
9 = Integrity
10 = Development complexity
11 = Performance
12 = Reusability
13 = Reliability
14 = Functional metrics (f_j)
15 = Complexity
16 = Functional complexity (FC)
17 = Functional complexity of an operating scenario

18 = Modularity
19 = Functional modularity
20 = Functional modularity of an operating scenario
21 = Redundancy
22 = Functional redundancy
23 = Fault tolerance
24 = Functional fault tolerance FT
25 = Involvement
26 = Functional involvement
27 = Coupling and cohesion
28 = Cohesion (CH)
29 = Coupling (KP)
30 = Efficiency
31 = Functional efficiency
32 = x … in relation to external resources
33 = Number
34 = Weighting factor w_j
35 = Sum of criterion weights
36 = Association matrix Z_{ij}

Figure 6a
As figure 4a
+ funktion = function

Figure 6b
As figure 4b

Figure 7
1 = Insertion of "nongenuine" or incorrect coins
2 = Insertion of 1 sent coins
3 = Insertion of 10 sent coins
4 = Insertion of 25 sent coins
5 = Acceptance of 1 sent coins
6 = Acceptance of 10 sent coins
7 = Acceptance of 25 sent coins
8 = Inserted coins
9 = * check coins for genuineness
10 = * return coins which are not genuine

11 = * genuine coins later used as change
12 = Product selection
13 = Selected product
14 = "Number and type of inserted coins"
15 = "Genuine"/correctly inserted money
16 = * coins as means of payment
17 = * accept product selection
18 = * goods dispensed with product available and sufficient money inserted
19 = * disable selection mode after goods dispensed
20 = "nongenuine"/incorrectly inserted coins
21 = Money returned if:
* too much has been paid (change)
* the customer wants money back
* the customer makes no selection
* if the product required is not available
22 = "Money returned!"
23 = "No product selection made"
24 = "Difference between inserted money/product price"
25 = "Product not available"
26 = Money returned
27 = "Prices changed"
28 = "Product range changed"
29 = Proceeds of sale collected
30 = New prices
31 = New product range
32 = Proceeds of sale
33 = * Product prices need to be changeable during maintenance
* The products offered need to be alterable
* Removal of collected proceeds of sale
34 = External interfaces (in/outputs)
35 = Internal interfaces, system boundary

Figure 8

1 = Memory
2 = Printer

3 = Mouse

4 = Keyboard

FIG 1

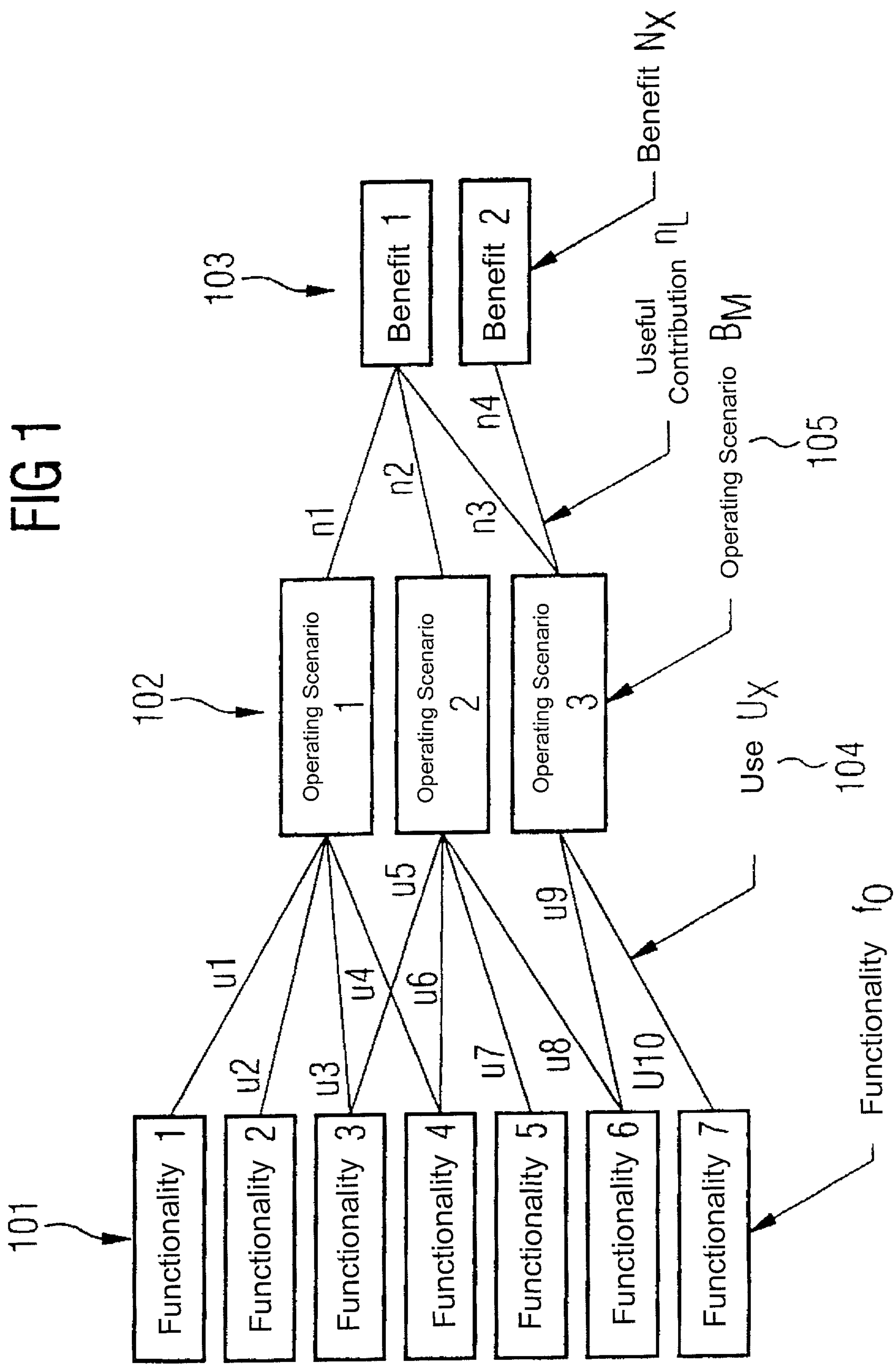

101
Functionality 1
Functionality 2
Functionality 3
Functionality 4
Functionality 5
Functionality 6
Functionality 7
u1
u2
u3
u4
u5
u6
u7
u8
u9
U10
102
Operating Scenario 1
Operating Scenario 2
Operating Scenario 3
n1
n2
n3
n4
103
Benefit 1
Benefit 2
Functionality f_O
Use U_X
104
Operating Scenario
105
Useful Contribution B_M
n_L
Benefit N_X

FIG 2

Structural Features	Functional Metrics	Usability	Modifiability	Maintainability	Checkability	Portability	Integrity	Development Complexity	Performance	Reusability	Reliability
Complexity											
	Functional Complexity FC		min.	—	—	—	—	min.	—	—	—
Functional Complexity of an Operating Scenario			min.	min.	min.	—	—	min.	min.	—	—
Modularity											
	Functional Modularity	—	max.	—	—	—	max.(x)	max.	—	—	—
Functional Complexity of an Operating Scenario		—	max.	max.	max.	—	max (x)	max.	—	max.	—
Redundancy											
	Functional Redundancy	—	—	—	—	—	—	—	—	—	max.
Fault Tolerance											
	Functional Fault Tolerance FT	—	—	—	—	max.(x)	max.(x)	—	—	—	max.
Involvement											
	Functional Involvement	—	—	—	—	min.(x)	min.(x)	—	—	—	min.
Coupling & Cohesion											
	Cohesion (CH)	—	max.	max.	max.	—	—	max.	—	max.	—
	Coupling (CP)	—	min.	min.	min.	—	—	min.	—	min.	—
Efficiency											
	Functional Efficiency	—	—	—	—	—	—	—	max.	—	—

(Quality Features: column group heading over Usability … Reliability)

x… in relation to external resources

FIG 3

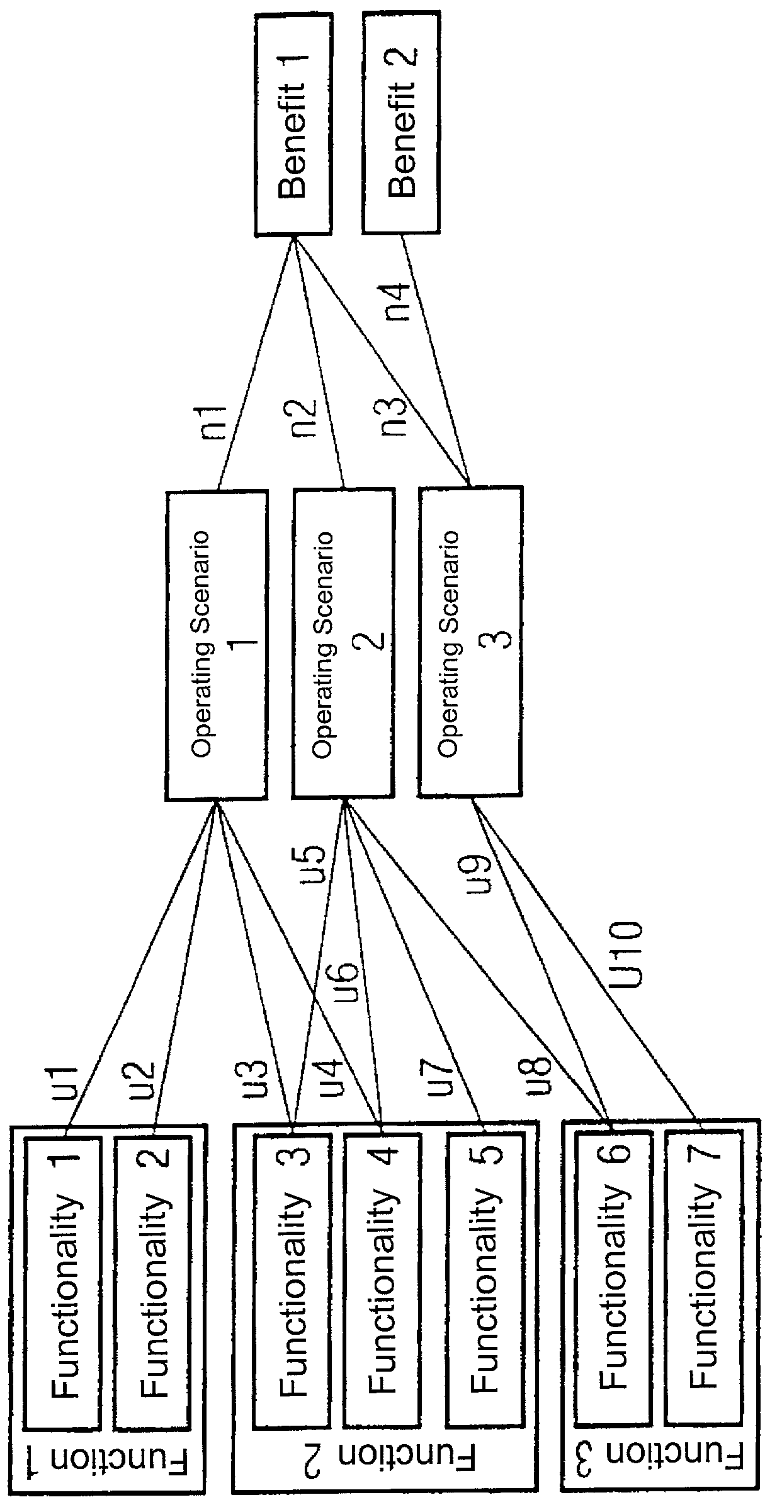

Benefit 1
Benefit 2
n1
n2
n3
n4
Operating Scenario 1
Operating Scenario 2
Operating Scenario 3
u1
u2
u3
u4
u5
u6
u7
u8
u9
U10
Functionality 1
Functionality 2
Functionality 3
Functionality 4
Functionality 5
Functionality 6
Functionality 7
Function 1
Function 2
Function 3

FIG 4A

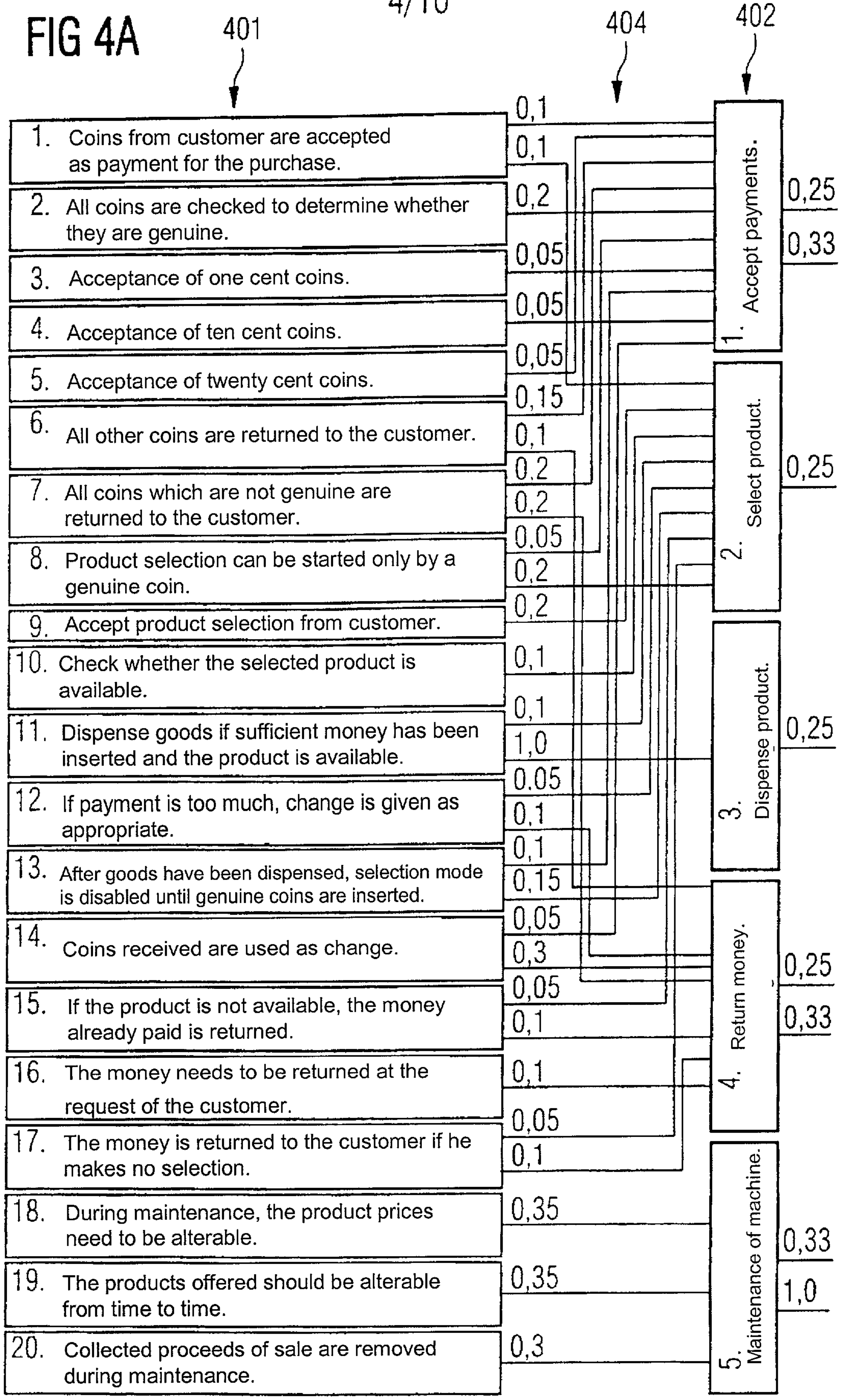
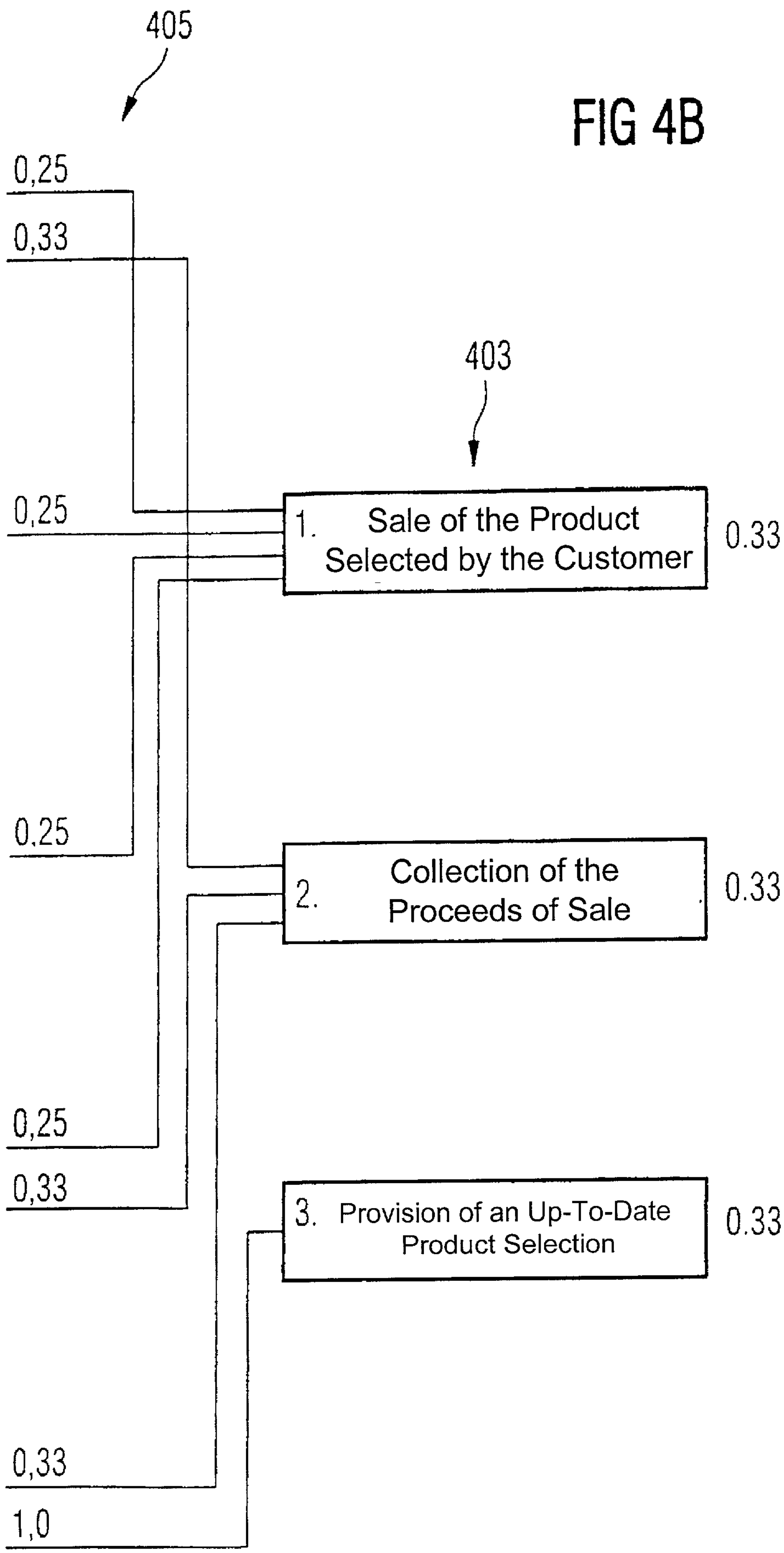

401
404
402
1. Coins from customer are accepted as payment for the purchase.
2. All coins are checked to determine whether they are genuine.
3. Acceptance of one cent coins.
4. Acceptance of ten cent coins.
5. Acceptance of twenty cent coins.
6. All other coins are returned to the customer.
7. All coins which are not genuine are returned to the customer.
8. Product selection can be started only by a genuine coin.
9. Accept product selection from customer.
10. Check whether the selected product is available.
11. Dispense goods if sufficient money has been inserted and the product is available.
12. If payment is too much, change is given as appropriate.
13. After goods have been dispensed, selection mode is disabled until genuine coins are inserted.
14. Coins received are used as change.
15. If the product is not available, the money already paid is returned.
16. The money needs to be returned at the request of the customer.
17. The money is returned to the customer if he makes no selection.
18. During maintenance, the product prices need to be alterable.
19. The products offered should be alterable from time to time.
20. Collected proceeds of sale are removed during maintenance.
0,1
0,1
0,2
0,05
0,05
0,05
0,15
0,1
0,2
0,2
0,05
0,2
0,2
0,1
0,1
1,0
0,05
0,1
0,1
0,15
0,05
0,3
0,05
0,1
0,1
0,05
0,1
0,35
0,35
0,3
1. Accept payments.
2. Select product.
3. Dispense product.
4. Return money.
5. Maintenance of machine.
0,25
0,33
0,25
0,25
0,25
0,33
0,33
1,0

FIG 4B


405
0,25
0,33
403
0,25
1. Sale of the Product Selected by the Customer
0.33
0,25
2. Collection of the Proceeds of Sale
0.33
0,25
0,33
3. Provision of an Up-To-Date Product Selection
0.33
0,33
1,0

09/980488

FIG 5

501 503 502

Association matrix Z_{ij}

Functional Metrics (Fj)		Usability	Modifiability	Maintainability	Checkability	Portability	Integrity	Development Complexity	Performance	Reusability	Reliability	Total:
Weighting (Q_i)		0.25	0.1	0.2	0.1	0	0	0.1	0	0.05	0.2	1
Complexity												
Functional Complexity (FC)	0.1583	1	1	0	0	0	0	1	0	0	0	
Functional Complexity of an Operating Scenario	0.2333	1	1	1	1	0	0	1	1	0	0	
Modularity												
Functional Modularity	0.0333	0	1	0	0	0	1	1	0	0	0	
Functional Complexity of an Operating Scenario	0.1250	0	1	1	1	0	1	1	0	1	0	
Redundancy												
Functional redundancy	0.0667	0	0	0	0	0	0	0	0	0	1	
Fault tolerance												
Functional fault tolerance FT	0.0667	0	0	0	0	1	1	0		0	1	
Involvement												
Functional involvement	0.0667	0	0	0	0	1	1	0	0	0	1	
Coupling and cohesion												
Cohesion (CH)	0.1250	0	1	1	1	0	0	1	0	1	0	
Coupling (KP)	0.1250	0	1	1	1	0	0	1	0	1	0	
Efficiency												
Functional efficiency	0.0000	0	0	0	0	0	0	0	1	0	0	
						x … in relation to external resources						
Weighting factor w_j — Number		2	6	4	4	2	4	6	2	3	3	
		0.5	0.1667	0.25	0.25	0.5	0.25	0.1667	0.5	0.3333	0.3333	
Sum of criterion weights	1.0000											

FIG 6A

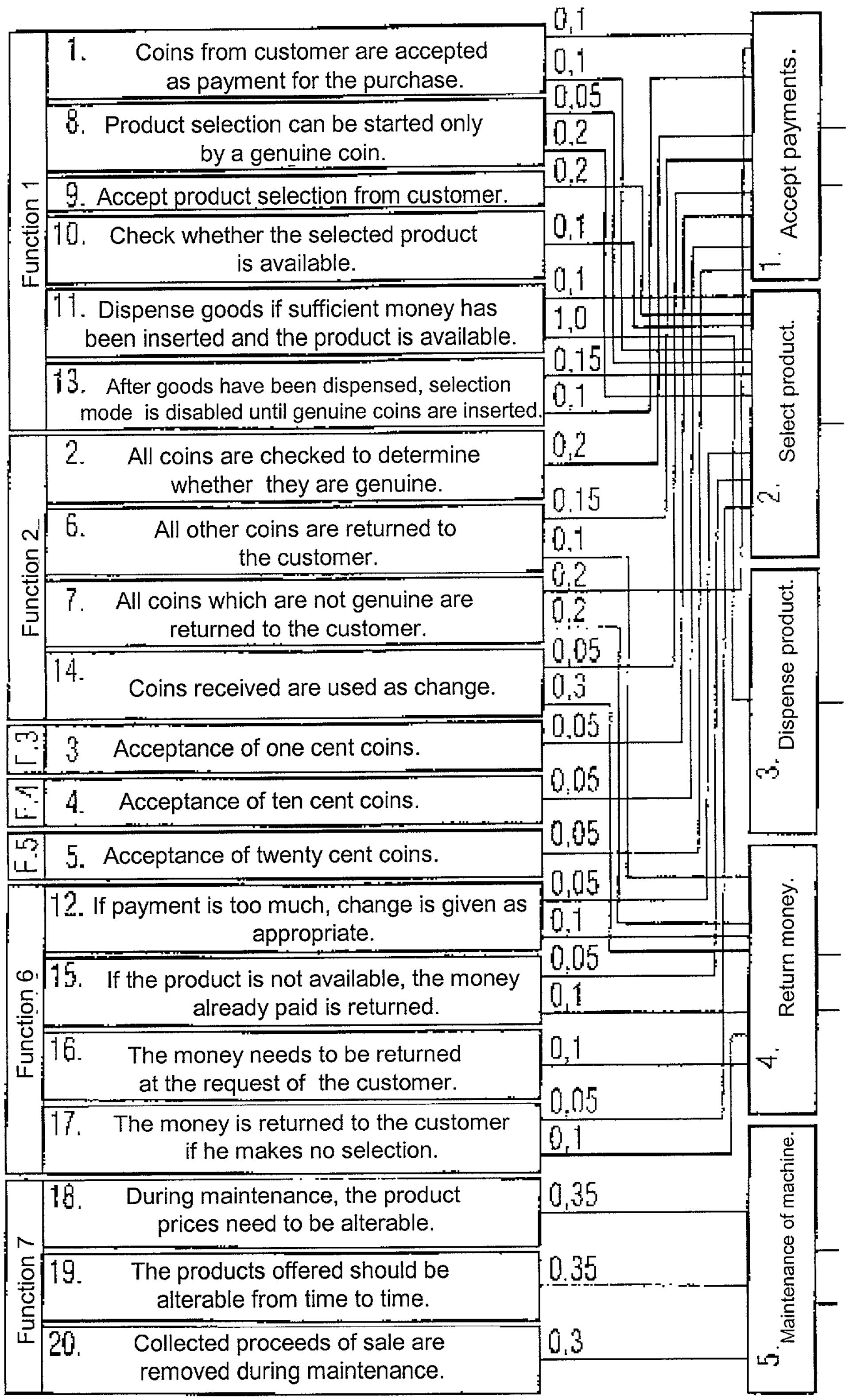
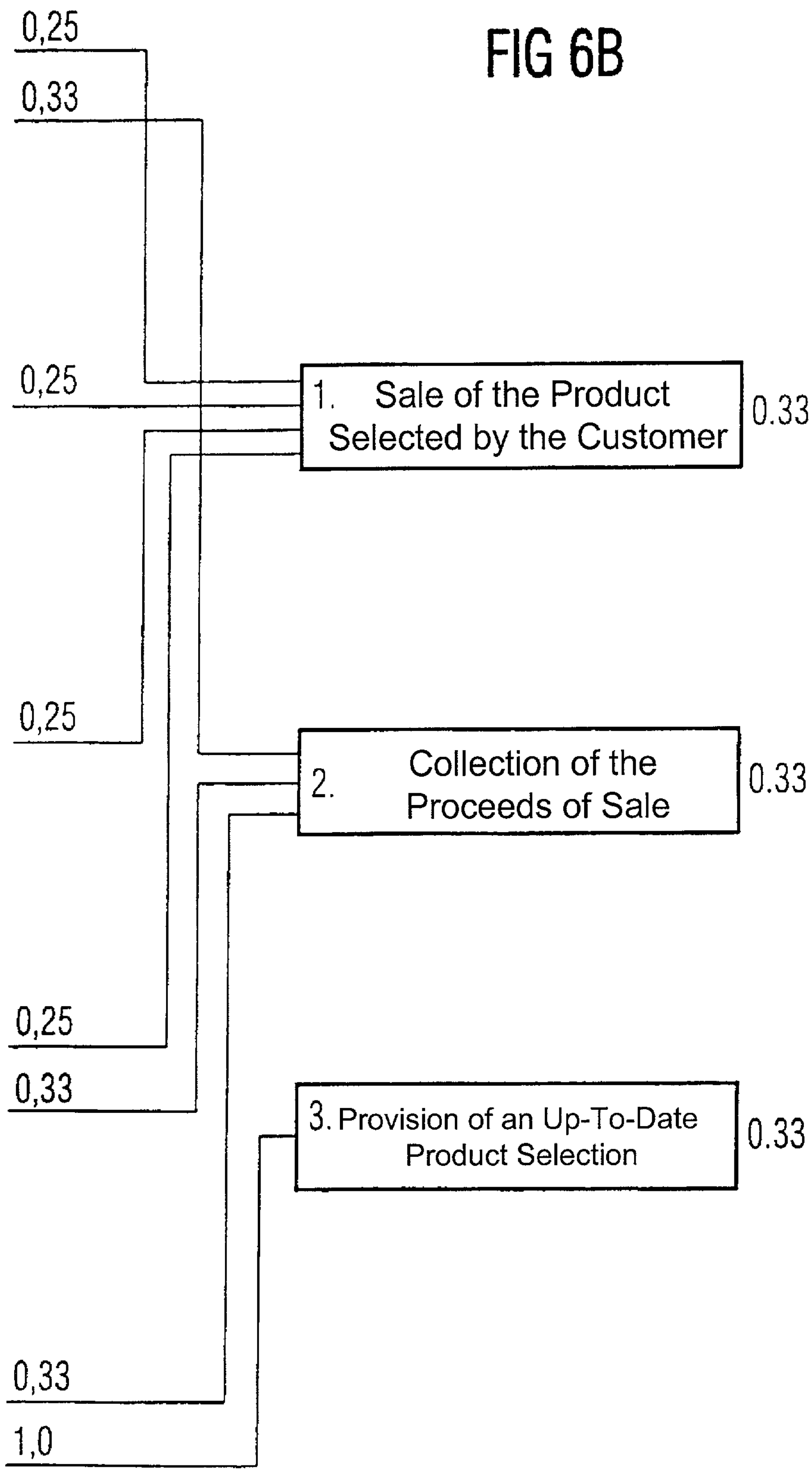

Function 1
1. Coins from customer are accepted as payment for the purchase.
8. Product selection can be started only by a genuine coin.
9. Accept product selection from customer.
10. Check whether the selected product is available.
11. Dispense goods if sufficient money has been inserted and the product is available.
13. After goods have been dispensed, selection mode is disabled until genuine coins are inserted.
Function 2
2. All coins are checked to determine whether they are genuine.
6. All other coins are returned to the customer.
7. All coins which are not genuine are returned to the customer.
14. Coins received are used as change.
F.3
3 Acceptance of one cent coins.
F.4
4. Acceptance of ten cent coins.
F.5
5. Acceptance of twenty cent coins.
Function 6
12. If payment is too much, change is given as appropriate.
15. If the product is not available, the money already paid is returned.
16. The money needs to be returned at the request of the customer.
17. The money is returned to the customer if he makes no selection.
Function 7
18. During maintenance, the product prices need to be alterable.
19. The products offered should be alterable from time to time.
20. Collected proceeds of sale are removed during maintenance.
0,1
0,1
0,05
0,2
0,2
0,1
0,1
1,0
0,15
0,1
0,2
0,15
0,1
0,2
0,2
0,05
0,3
0,05
0,05
0,05
0,05
0,1
0,05
0,1
0,1
0,05
0,1
0,35
0,35
0,3
1. Accept payments.
2. Select product.
3. Dispense product.
4. Return money.
5. Maintenance of machine.

FIG 6B


0,25
0,33
0,25
1. Sale of the Product Selected by the Customer
0.33
0,25
2. Collection of the Proceeds of Sale
0.33
0,25
0,33
3. Provision of an Up-To-Date Product Selection
0.33
0,33
1,0

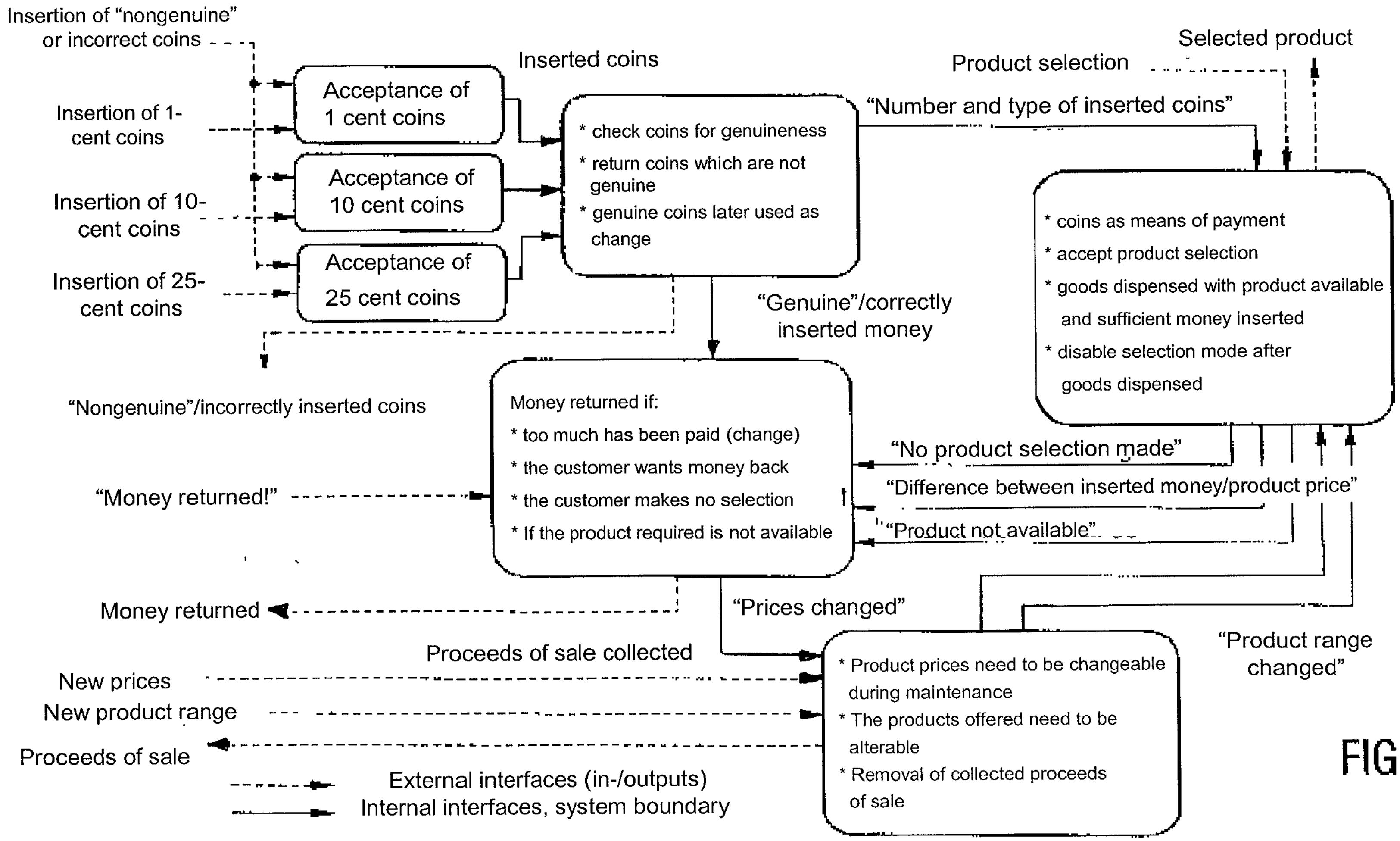
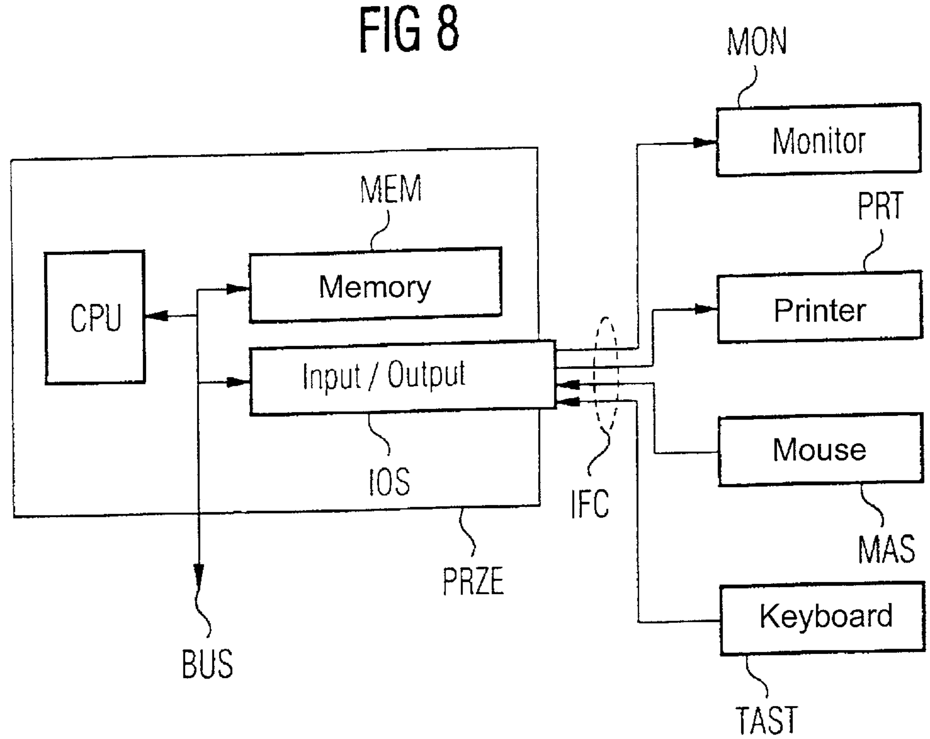

Insertion of "nongenuine" or incorrect coins
Insertion of 1-cent coins
Insertion of 10-cent coins
Insertion of 25-cent coins
Acceptance of 1 cent coins
Acceptance of 10 cent coins
Acceptance of 25 cent coins
Inserted coins
* check coins for genuineness
* return coins which are not genuine
* genuine coins later used as change
"Nongenuine"/incorrectly inserted coins
"Genuine"/correctly inserted money
"Number and type of inserted coins"
Product selection
Selected product
* coins as means of payment
* accept product selection
* goods dispensed with product available and sufficient money inserted
* disable selection mode after goods dispensed
"Money returned!"
Money returned if:
* too much has been paid (change)
* the customer wants money back
* the customer makes no selection
* If the product required is not available
"No product selection made"
"Difference between inserted money/product price"
"Product not available"
Money returned
"Prices changed"
"Product range changed"
Proceeds of sale collected
New prices
New product range
Proceeds of sale
* Product prices need to be changeable during maintenance
* The products offered need to be alterable
* Removal of collected proceeds of sale
External interfaces (in-/outputs)
Internal interfaces, system boundary

FIG 7

FIG 8


MON
Monitor
PRT
Printer
MEM
Memory
CPU
Input / Output
IOS
IFC
Mouse
MAS
Keyboard
TAST
PRZE
BUS

Declaration and Power of Attorney for Patent Application
Erklärung für Patentanmeldungen mit Vollmacht

German Language Declaration

Als nachstehend benannter Erfinder erkläre ich hiermit an Eides Statt:

daß mein Wohnsitz, meine Postanschrift und meine Staatsangehörigkeit den im nachstehenden nach meinem Namen aufgeführten Angaben entsprechen, daß ich nach bestem Wissen der ursprüngliche, erste und alleinige Erfinder (falls nachstehend nur ein Name angegeben ist) oder ein ursprünglicher, erster und Miterfinder (falls nachstehend mehrere Namen aufgeführt sind) des Gegenstandes bin, für den dieser Antrag gestellt wird und für den ein Patent für die Erfindung mit folgendem Titel beantragt wird:

____

____

deren Beschreibung hier beigefügt ist, es sei denn (in diesem Falle Zutreffendes bitte ankreuzen), diese Erfindung

☐ wurde angemeldet am __________
unter der US-Anmeldenummer oder unter der Internationalen Anmeldenummer im Rahmen des Vertrags über die Zusammenarbeit auf dem Gebiet des Patentwesens (PCT)
______________ und am
______________ abgeändert (falls zutreffend).

Ich bestätige hiermit, daß ich den Inhalt der oben angegebenen Patentanmeldung, einschließlich der Ansprüche, die eventuell durch einen oben erwähnten Zusatzantrag abgeändert wurde, durchgesehen und verstanden habe.

Ich erkenne meine Pflicht zur Offenbarung jeglicher Informationen an, die zur Prüfung der Patentfähigkeit in Einklang mit Titel 37, Code of Federal Regulations, § 1.56 von Belang sind.

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

METHOD, SYSTEM AND COMPUTER PROGRAM FOR DESIGNING A TECHNICAL SYSTEM

____

the specification of which is attached hereto unless the following box is checked:

☒ was filed on 3 December 2001
as United States Application Number or PCT International Application Number
______________ and was amended on
______________ (if applicable).

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations, § 1.56.

German Language Declaration

Ich beanspruche hiermit ausländische Prioritätsvorteile gemäß Title 35, US-Code, § 119 (a)-(d), bzw. § 365(b) aller unten aufgeführten Auslandsanmeldungen für Patente oder Erfinderurkunden, oder § 365(a) aller PCT internationalen Anmeldungen, welche wenigstens ein Land ausser den Vereinigten Staaten von Amerika benennen, und habe nachstehend durch ankreuzen sämtliche Auslands- anmeldungen für Patente bzw. Erfinderurkunden oder PCT internationale Anmeldungen angegeben, deren Anmeldetag dem der Anmeldung, für welche Priorität beansprucht wird, vorangeht.

I hereby claim foreign priority under Title 35, United States Code, § 119(a)-(d) or § 365(b) of any foreign application(s) for patent or inventor's certificate, or § 365(a) of any PCT International application which designated at least one country other than the United States, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate, or PCT International application having a filing date before that of the application on which priority is claimed.

Prior Foreign Applications
(Frühere ausländische Anmeldungen)

(Number) (Nummer)	(Country) (Land)	(Day/Month/Year Filed) (Tag/Monat/Jahr der Anmeldung)	Priority Not Claimed / Priorität nicht beansprucht
19925214.9	Germany	01 June 1999	☐
			☐

Ich beanspruche hiermit Prioritätsvorteile unter Title 35, US-Code, § 119(e) aller US-Hilfsanmeldungen wie unten aufgezählt.

I hereby claim the benefit under Title 35, United States Code, § 119(e) of any United States provisional application(s)listed below.

(Application No) (Aktenzeichen)	(Filing Date) (Anmeldetag)

Ich beanspruche hiermit die mir unter Title 35, US-Code, § 120 zustehenden Vorteile aller unten aufgeführten US-Patentanmeldungen bzw. § 365(c) aller PCT internationalen Anmeldungen, welche die Vereinigten Staaten von Amerika benennen, und erkenne, insofern der Gegenstand eines jeden früheren Anspruchs dieser Patentanmeldung nicht in einer US-Patentanmeldung, bzw. PCT internationalen Anmeldung in in einer gemäß dem ersten Absatz von Title 35, US-Code, § 112 vorgeschriebenen Art und Weise offenbart wurde, meine Pflicht zur Offenbarung jeglicher Informationen an, die zur Prüfung der Patentfähigkeit in Einklang mit Title 37, Code of Federal Regulations, § 1.56 von Belang sind und die im Zeitraum zwischen dem Anmeldetag der früheren Patentanmeldung und dem nationalen oder im Rahmen des Vertrags über die Zusammenarbeit auf dem Gebiet des Patentwesen (PCT) gültigen internationalen Anmeldetags bekannt geworden sind.

I hereby claim the benefit under Title 35, United States Code, § 120 of any United States application(s), or § 365(c) of any PCT International application designating the United States, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application in the manner provided by the first paragraph of Title 35, United States Code, § 112, I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations, § 1.56 which became available between the filing date of the prior application and the national or PCT International filing date of this application.

(Application No.) (Aktenzeichen)	(Filing Date) (Anmeldetag)	(Status) (patented, pending, abandoned) (Status) (patentiert, schwebend, aufgegeben)
PCT/DE00/01528	15 May 2000	pending

Ich erkläre hiermit, daß alle in der vorliegenden Erklärung von mir gemachten Angaben nach bestem Wissen und Gewissen der Wahrheit entsprechen, und ferner daß ich diese eidesstattliche Erklärung in Kenntnis dessen ablege, daß wissentlich und vorsätzlich falsche Angaben oder dergleichen gemäß § 1001, Title 18 des US-Code strafbar sind und mit Geldstrafe und/oder Gefängnis bestraft werden können und daß derartige wissentlich und vorsätzlich falsche Angaben die Rechtswirksamkeit der vorliegenden Patentanmeldung oder eines aufgrund deren erteilten Patentes gefährden können.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon

PTO/SB/103 (8-96)
Approved for use through 9/30/98. OMB 0651-0032
Patent and Trademark Office: U.S. DEPARTMENT OF COMMERCE

German Language Declaration

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POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith: *(list name and registration number)*

Postanschrift:

Send Correspondence to:

STAAS & HALSEY LLP

21171

Vor- und Zuname des einzigen oder ersten Erfinders 1-00	Full name of sole or first inventor Thilo-Florian HARZENETTER
Unterschrift des Erfinders Datum	~~Inventor's signature~~ Date 21.01.02
Wohnsitz	Residence Muenchen, Germany DEX
Staatsangehörigkeit	Citizenship German
Postanschrift	Post Office Address Entenbachstrasse 50
	81541 Muenchen, Germany
Vor- und Zuname des zweiten Miterfinders (falls zutreffend) 2-00	Full name of second joint inventor, if any Bernhard THOME
Unterschrift des zweiten Erfinders Datum	Second Inventor's signature Bernhard Thome Date 12 Jan 2002
Wohnsitz	Residence Stuttgart, Germany DEX
Staatsangehörigkeit	Citizenship German
Postanschrift	Post Office Address Köpfertstrasse 23
	70599 Stuttgart, Germany

(Im Falle dritter und weiterer Miterfinder sind die entsprechenden Informationen und Unterschriften hinzuzufügen.)

(Supply similar information and signature for third and subsequent joint inventors.)